

New Scientist

WEEKLY 2 January 2021

2021 PREVIEW

When will life get back to normal?

A year of climate action

Onwards to Mars

Microplastic risk exposed

The books you mustn't miss

How old is it?

How big is it?

What does it weigh?

THE STATE OF THE UNIVERSE

A SPECIAL ISSUE

What shape is it?

How fast is it growing?

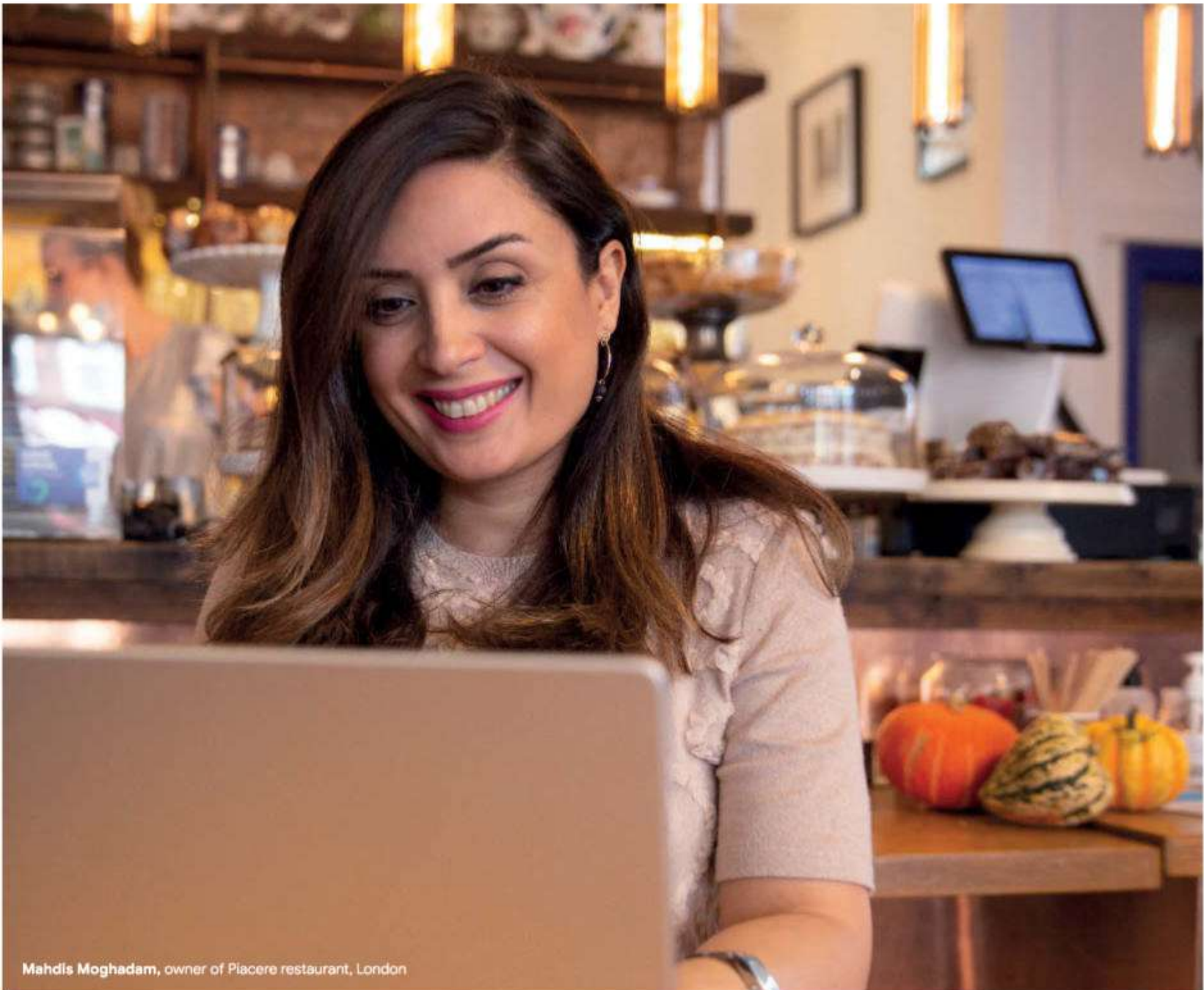
How long will it last?

PLUS

INSIDE DEEPMIND: EXCLUSIVE INTERVIEW WITH DEMIS HASSABIS
ON USING AI TO SOLVE HUMANITY'S BIGGEST PROBLEMS

No3315 £5.95 CAN\$7.99

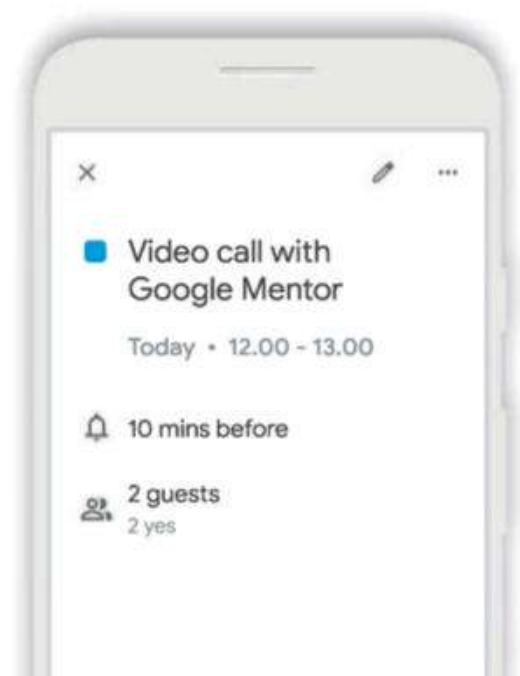




Google is providing free 1-to-1 mentoring to help your business adapt.

We're helping local businesses across the UK adapt to new ways of working.

Find free tools for you and your business at g.co/helpforbusiness



On the cover

32 The state of the universe

How old is it?
How big is it?
What does it weigh?
What shape is it?
How fast is it growing?
How long will it last?



Vol 249 No 3315
Cover image: Andy Gilmore

2021 preview

- 8 When will life get back to normal?
- 16 A year of climate action
- 13 Onwards to Mars
- 14 Microplastic risk exposed
- 24 The books you mustn't miss

44 Inside DeepMind

Exclusive interview with Demis Hassabis on using AI to solve humanity's biggest problems

39 Features

“*Candida auris* is scary – it can live on surfaces for long periods and withstand whatever you throw at it”

News preview

8 Coronavirus

Will vaccines help life return to normal?

14 Plastic pollution

Are tiny pieces of plastic harmful to human health?

16 Climate change

As countries pledge to hit net-zero emissions, will 2021 be a year of climate action?

Views

19 Comment

Becca Caddy on how to reach a balance with your tech devices

20 The columnist

James Wong on the truth about raw-food diets

22 Letters

This magazine saved me from creationist views

24 Culture

The science books of 2021 you mustn't miss

28 Aperture

Mapping the hidden phenomena of Antarctica

News preview



13 Mars touchdown Perseverance is one of three upcoming missions

Features

32 State of the universe

The essential guide to what we know about the universe – and what we still need to find out

39 The other superbugs

Deadly, drug-resistant fungi are on the rise

44 Demis Hassabis interview

The co-founder of DeepMind on how AI will crack the toughest scientific problems

The back pages

51 Science of gardening

Give your potatoes a head start

52 Puzzles

Try our quick crossword, quiz and brain-teaser

54 Almost the last word

Why don't birds freeze when flying at high altitudes?

56 Feedback

Elevator arrivals and dam dilemmas: the week in weird

56 Twisteddoodles for New Scientist

Picturing the lighter side of life

Virtual events

Ten keys to reality with Frank Wilczek

The first talk in our new Big Ideas in Physics series sees legendary scientist Frank Wilczek explain how we arrived at our modern understanding of reality – a bigger and stranger picture than ever before. Join us on 28 January from 6pm GMT. Tickets available now.

[newscientist.com/events](https://www.newscientist.com/events)

Podcasts

Weekly

The big science stories to watch in 2021, from Mars missions to coronavirus, climate change to microplastics. The team also shares cultural picks for the coming year.

[newscientist.com/podcasts](https://www.newscientist.com/podcasts)

Newsletter

Lost in space-time

Our brand new monthly newsletter from executive editor Richard Webb covers all that's hot in the world of fundamental physics. Sign up now.

[newscientist.com/
sign-up/lost-in-
space-time](https://www.newscientist.com/sign-up/lost-in-space-time)

Virtual event



Time, space, matter Frank Wilczek is your guide to understanding it all

Podcast



SHUTTERSTOCK/DAVID PEREIRAS

Pretty deadly Will we start to tackle microplastics properly this year?

Newsletter



NASA/CXC/M. WEISS/SCIENCE PHOTO LIBRARY

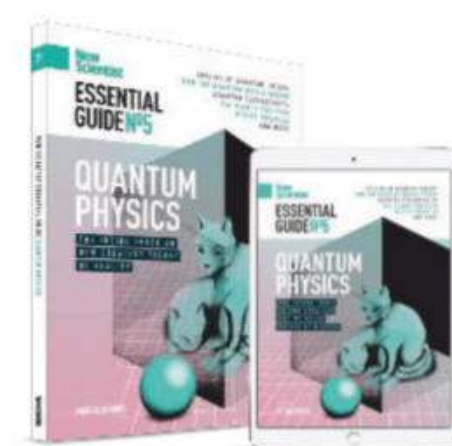
Ravenous beasts Do black holes eat everything, even information?

Online

Covid-19 daily briefing

All the most important developments of the pandemic in one essential briefing, plus links to our latest exclusive news, features and interviews. Updated daily at 6pm GMT from 4 January.

[newscientist.com/
coronavirus-latest](https://www.newscientist.com/coronavirus-latest)



Essential guide

Get the lowdown on our greatest and weirdest theory of reality – dead-and-alive cats and all – with *Essential Guide: Quantum physics*, the fifth instalment in our series.

shop.newscientist.com



Photo: Christina Wocintechchat

2021: A new year to rethink food

After a year of confusing and often misleading news about food, why not learn something new in 2021?

This year is a chance for the world to build back better and create a food system that works for everyone. By joining one of EIT Food's online flexible education courses, you will be empowered to 'rethink' food and make more informed food choices.

Interested? Sign up today for free:
www.futurelearn.com/connect-with-food

EIT Food is
Europe's leading
food innovation
initiative

**Here's a selection of our current
free online courses:**

- **Superfoods: Myths and Truths**
What is a 'superfood'? And what effect do they have on the body and society?
- **Food and Nutrition: The Truth Behind the Headlines**
Learn how to find reliable, scientific information about food and nutrition, and understand why people are often easily influenced by the headlines.
- **An Introduction to Food Science**
By understanding and learning more about what's in food with this course, you will be able to make smarter, more sustainable and healthier food choices.
- **The Human Microbiome**
Discover what the microbiome is, how it changes throughout your life, and the role it plays in good human health.

Thinking about exploring the world again?

While travel has been little more than a dream over the past year, we know that many of you are now eager to plan your next adventure. We are now taking bookings for our 2021 and 2022 tours.

- Over 40 departures
- Small group sizes
- Transferable deposits and deposit refunds should Covid impact departure dates
- Safe touring protocols with your protection in mind

For more information on
all our new tours for 2021, visit
newscientist.com/tours



GREECE

Learn to dig Mycenaean archaeology

7 days | 14 May and 4 June 2021

An interactive tour of the key Mycenaean sites including a unique 'behind the ropes' 3-day experience at Mycenae where you will be taught how to explore, map and excavate with their resident archaeologists.



MALTA

Megalithic Malta: Temples, fortifications and archaeology

6 days | 17 May and 1 Nov 2021

Malta and Gozo are small islands with a long and fascinating history including exceptional archaeological sites. From the ancient and mysterious temples believed to be some of the world's oldest structures, to the fortifications of the Knights of St John. Discover over 7000 years of history.

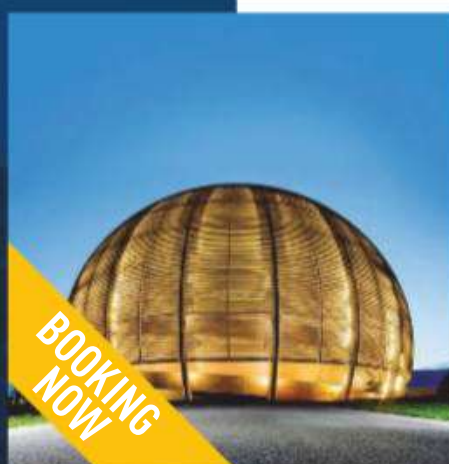


CZECH REPUBLIC

Kepler's Prague: Astronomy and the music of the spheres

6 days | 14 April and 14 Sept 2021

Discover the legacy of Kepler and Brahe where astronomy, maths, music and art connect in the city of a hundred spires. Our tour with author and broadcaster Jane Green will journey to the heart of early science and Prague's medieval marvels.



SWITZERLAND AND FRANCE

CERN and Mont Blanc: Dark and Frozen Matter

6 days | 11 May and 15 Sept 2021

Visit one of the world's most important science and innovation centres in charming Geneva, home to the large Hadron Collider. Our tour will delve into the history of this lakeside town before proceeding to the Alps to explore its receding glaciers.

Our big moment

How we reboot the world as the coronavirus pandemic dies down will be critical

IT MAY be a new year, but the same old question lingers: when will life get back to normal? This dominates the opening pages of our preview of 2021 (see page 8).

A better question, though, is what kind of normal should we be striving for now? Because, as any climate scientist will tell you, the old one was doing us few favours in the long term. This is the focus of another part of our preview (page 16).

It is understandable and right that governments are taking steps to get economies back on their feet, as mass vaccination programmes get going, hopefully marking the beginning of the end of the pandemic. What is key now is what kind of recovery politicians opt for, because this is what is going to decide our collective climate future.

The UN estimates a truly green recovery worldwide – one in which

renewable energy and electric cars are turbocharged – could shave 25 per cent off pre-covid expectations for global emissions in 2030. Researchers have estimated a green stimulus could avoid 0.3°C of warming by 2050, a huge number in climate change terms.

“Failure to tackle emissions will lead to a new normal that no one wants – a climate crisis that dwarfs covid-19”

The pandemic could, in its way, help here. The disaster has shown the importance of following the science. It has also spurred a public thirst for more scientific information.

In July, a landmark report from the UN climate science panel, the IPCC, will set out the very latest understanding of

climate change science. Let us hope that the world listens and follows that science.

That means, collectively, countries halving emissions by 2030, and cutting them to net zero by mid-century. Failure to do this could lead to a new normal that none of us wants – a climate crisis that completely dwarfs covid-19.

Fortunately, any new-found faith in science aside, we do enter 2021 with some positive tailwinds. Three big emitters, the EU, China and US, have all committed to producing new plans this year for reining in emissions by 2030.

Presuming that fears of gathering in public recede this year, pressure from climate-striking teenagers and others may also prove crucial in holding our leaders' feet to the fire.

The long and the short of it, though, is: we can succeed, and we must. ■

PUBLISHING & COMMERCIAL

Commercial and events director Adrian Newton

Display advertising

Tel +44 (0)20 7611 1291 **Email** displayads@newscientist.com

Sales director Justin Viljoen

Sales manager Rosie Bolam

Recruitment advertising

Tel +44 (0)20 7611 1204 **Email** nssales@newscientist.com

Recruitment sales manager Viren Vadgama

New Scientist Events

Tel +44 (0)20 7611 1245 **Email** live@newscientist.com

Creative director Valerie Jamieson

Sales director Jacqui McCarron **Event manager** Henry Gomm

Marketing manager Emiley Partington

Events team support manager Rose Garton

New Scientist Discovery Tours

Director Kevin Currie

Marketing

Marketing director Jo Adams

Head of campaign marketing James Nicholson

Head of customer experience Emma Robinson

Email/CRM manager Rose Broomes

Digital marketing manager Craig Walker

Customer experience marketing manager Esha Bhabuta

Digital & Data

Digital product development director Laurence Taylor

Head of audience data Rachael Dunderdale

Technology

CTO and programme director Debora Brooksbank-Taylor

Head of technology Tom McQuillan

Maria Moreno Garrido, Amardeep Sian,

Ben Townsend, Piotr Walków

NewScientist

Chief executive Nina Wright

Executive assistant Lorraine Lodge

Finance & operations

Chief financial officer Amee Dixon

Financial controller Taryn Skorjenko

Management Accountant Alfred Princwill

Facilities manager Ricci Welch

Receptionist Alice Catling

Human resources

Human resources director Shirley Spencer

HR business partner Katy Le Poidevin

Non executives

Non-exec chair Bernard Gray

Senior non-exec director Louise Rogers

CONTACT US

newscientist.com/contact

General & media enquiries

UK **Tel** +44 (0)20 7611 1200

25 Bedford Street, London WC2E 9ES

Australia 418A Elizabeth St, Surry Hills, NSW 2010

US PO Box 80247, Portland, OR 97280

UK Newsstand

Marketforce UK Ltd **Tel** +44 (0)33 0390 6555

Syndication

Tribune Content Agency **Tel** +44 (0)20 7588 7588

Email tca-articlesales@tribpub.com

Subscriptions

newscientist.com/subscribe

Tel +44 (0)330 333 9470

Email subscriptions@newscientist.com

Post New Scientist, Rockwood House, Perrymount Road, Haywards Heath, West Sussex RH16 3DH

EDITORIAL

Editor Emily Wilson

Executive editor Richard Webb

Creative director Craig Mackie

News

News editor Penny Sarchet

Editors Jacob Aron, Chelsea Whyte

Reporters (UK) Jessica Hamzelou, Michael Le Page,

Layal Liverpool, Adam Vaughan, Clare Wilson

(US) Leah Crane, (Aus) Alice Klein, Donna Lu

Interns Ibrahim Sawal, Karina Shah, Krista Charles

Digital

Digital editor Conrad Quilty-Harper

Podcast editor Rowan Hooper

Web team Emily Bates, Anne Marie Conlon, Alexander McNamara, David Stock, Sam Wong

Features

Head of features Catherine de Lange and Tiffany O'Callaghan

Editors Daniel Cossins, Kate Douglas,

Alison George, Joshua Howgego

Feature writer Graham Lawton

Culture and Community

Comment and culture editor Timothy Revell
Liz Else

Subeditors

Chief subeditor Eleanor Parsons

Bethan Ackerley, Tom Campbell,

Chris Simms, Jon White

Design

Art editor Kathryn Brazier

Joe Hetzel, Ryan Wills

Picture desk

Picture editor Helen Benians

Tim Boddy

Production

Production manager Joanne Keogh
Robin Burton



© 2020 New Scientist Ltd, England. New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Precision Colour Printing Ltd

Wrap up warm for an Ice Age Adventure!

AQUILA Magazine is a big hit in the world of children's publishing: its thought-provoking topics are so well researched and written you will probably enjoy reading the articles yourself.

In the January issue, children can join an exciting expedition back to the last glacial period.

New topics for Spring 2021:

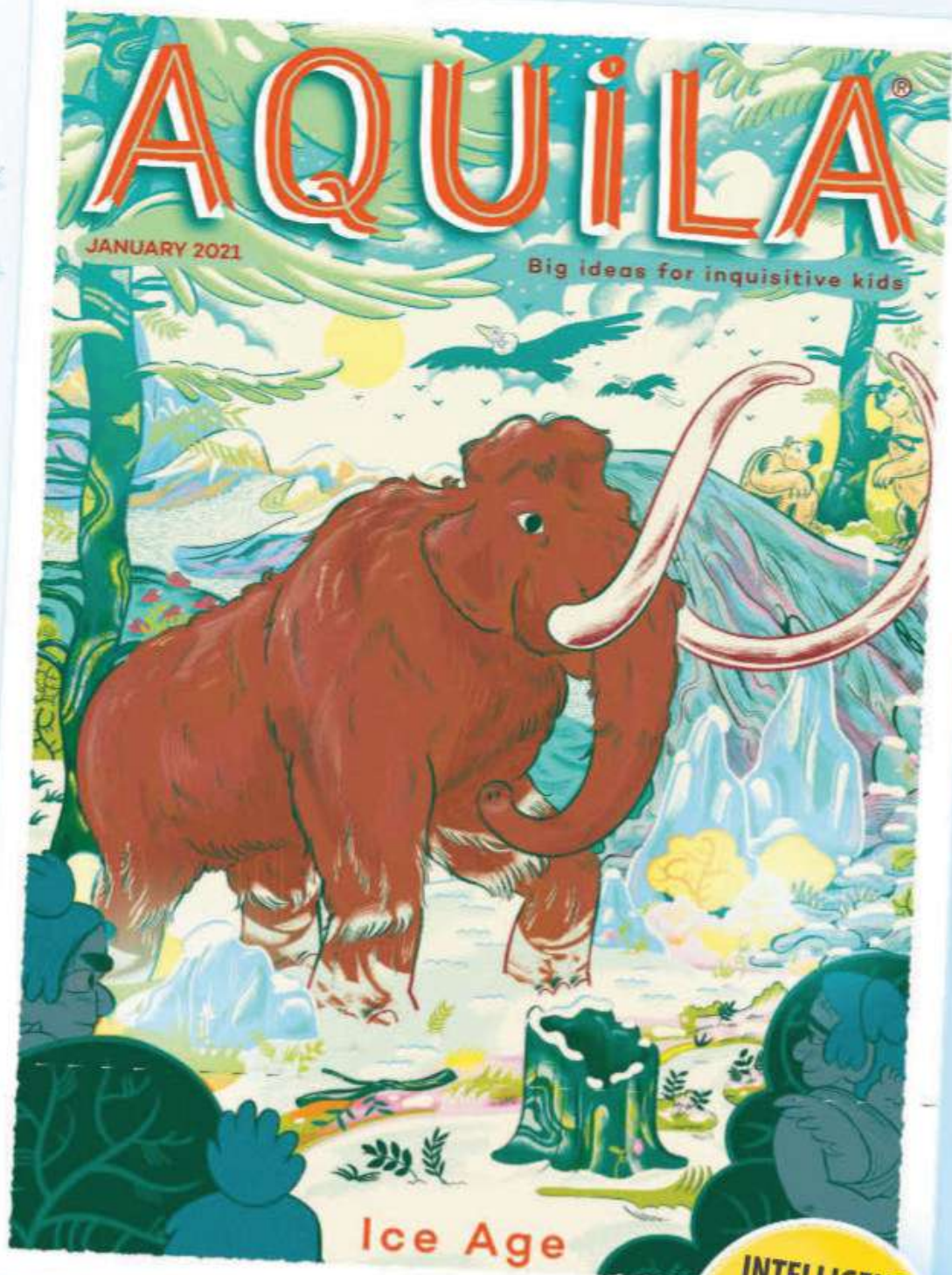
February: FUNFAIR MATHS

This dazzling topic investigates the weird paradoxes and mind-bending concepts that are present in the world of mathematics.

March: BRILLIANT BUGS from the beautifully iridescent and the downright scary insects that share our planet to those nasty digital bugs that spoil our time online.

April: a visit to **ANCIENT EGYPT** and the River Nile makes for a very popular topic – so not to be missed!

- ✓ **BIG IDEAS** for Curious Minds
- ✓ **A Book's Worth of Reading**
- ✓ **Brilliant New Topic Every Month!**



Imagine Earth's northern lands when they were frozen into one gigantic continent: take part in a Mammoth Hunt and meet Inuit people who know how to survive freezing temperatures. **PLUS:** Icy Experiments, Dog Sledding and the Story of Ice Cream!

**INTELLIGENT
FACTS
& Serious FUN
Every Month**



Subscriptions include:

- 1 With the first issue:** a Mega Wall Map & Passport Puzzler, plus your own Personal Gift Message
- 2 FREE EXTRAS:** every month, top-notch topic extension materials are available to download for the most dedicated AQUILAnauts to take their learning a step further!
- 3 50% OFF** back-issues when you subscribe

www.AQUILA.co.uk

Creative, Funny & Inspiring

AQUILA is not like any other children's publication you have seen, and you won't find it on the newsstand; the editorial is witty and sophisticated, making children feel part of a very special club!

Highly recommended reading for bright 8–13-year-olds, every monthly topic brings a well-balanced feast of Science, Arts and General Knowledge into the family home, encouraging children to think beyond the school curriculum and to become self-motivated learners.

"...Advanced & Philosophical, Curious & Puzzling"

RICHARD ROBINSON – BRIGHTON SCIENCE FESTIVAL

Preview of 2021

Coronavirus

Will vaccines help life return to normal this year? **p8**

Onwards to Mars

Three spacecraft are about to explore the Red Planet **p13**

Plastic pollution

We may finally know whether microplastics harm our health **p14**

Climate action

Key events will make 2021 a crucial year for climate change **p16**

Hello 2021

The coronavirus pandemic and the climate crisis loom large, but there is also hope on the horizon



Physician Alister Martin was given one of the US's first doses of the Pfizer and BioNTech vaccine at Massachusetts General Hospital in Boston on 16 December 2020. This year, millions more people are expected to receive one of a range of vaccines

CRAIG F. WALKER/POOL VIA REUTERS

Coronavirus

When will life return to normal?

We start the new year with effective coronavirus vaccines, but the end of the pandemic is still a way off. So what will life be like in 2021, as we glimpse the beginning of the end of the crisis, ask **Graham Lawton**, **Michael Le Page**, **Donna Lu**, **Clare Wilson** and **Adam Vaughan**



Restrictions and lockdowns are likely to be part of life for months to come



IF 2020 felt hellish, be warned that we aren't out of the fire yet, even if we are moving in the right direction. Welcome to 2021, aka purgatory.

There is little doubt that vaccines hold the key to ending the pandemic. A recent modelling study predicted that vaccinating just 40 per cent of US adults over the course of 2021 would reduce the coronavirus infection rate by around 75 per cent and cut hospitalisations and deaths from covid-19 by more than 80 per cent.

But all this is still some way off. In the meantime, we will have to adapt to a middle ground where some people are protected but not others. As Adam Kleczkowski, a mathematical biologist at the University of Strathclyde, UK, points out, supplies of the various vaccines are limited, distributing them is challenging, immunity takes a few weeks to develop and the protection they offer isn't 100 per cent.

In the northern hemisphere, he says, the most likely scenario is a third wave of covid-19 in the new year, requiring further lockdowns and restrictions for up to five months. "Realistically, we're in for a longer ride than we hope for," he says.

Tim Spector at King's College London,

who leads the Covid-19 Symptom Study in the UK, also predicts a third wave. But if lots of healthcare workers and vulnerable people have been vaccinated, the mortality rate will be lower and the pressure on the healthcare system lessened, he said at a recent Royal Society of Medicine seminar.

The upsides of ever-widening vaccination will kick in around April, he said. "I'm optimistic that if we can just get our mental state together until Easter, we can hang on in there."

There are still many things we don't understand about this virus, however (see "Unanswered questions", page 10), and we may well be in for some surprises in the coming year that throw that trajectory off course. As this magazine went to press, for example, there was widespread speculation about the impact of a new variant of the SARS-CoV-2 coronavirus circulating in the UK that may be more highly transmissible.

In Australia, the goal will be to keep the virus from resurging as the summer fades into autumn, says epidemiologist Catherine Bennett at Deakin University in Melbourne. A recent outbreak in Sydney has led to new restrictions.



People enjoy the sun while social distancing in Melbourne, Australia, in October 2020 after restrictions eased

its residents twice. It also has options to buy 152 million more doses. The European Union has secured 1.3 billion doses, while Canada has bought enough doses to vaccinate five times its population.

COVAX, a vaccine allocation coalition co-led by the World Health Organization (WHO), is aiming to distribute 2 billion doses to 92 low and middle-income countries by the end of 2021 at a maximum price of \$3 per dose. This is enough to vaccinate all health and social care workers by the middle of 2021 in participating countries that have asked for doses in that time frame, and would cover 20 per cent of people in the other countries – those most vulnerable. To achieve this, COVAX still needs a further \$6.8 billion by the end of 2021. It has no supplies of the vaccine made by Pfizer and BioNTech that is already being rolled out in some countries, including the UK and US.

The US has ordered enough doses of the vaccines created by Pfizer/BioNTech and Moderna to immunise 150 million people – less than half the population – by the end of June. It recently asked Pfizer for doses to immunise an additional 50 million people, but the firm has already promised all of the doses it can feasibly produce by mid-2021 to other countries.

Even in wealthy countries with adequate doses of covid-19 vaccines, immunising the entire population will take time. In the UK, it will take nearly a year, according to Jeremy Farrar, director of Wellcome and a member of the UK government's SAGE advisory committee. "1000 vaccination centres each vaccinating 500 people a day for 5 days a week, without interruptions of supply or delivery, would take almost a year to provide two doses to the UK population," he wrote in the journal *Anaesthesia*.

The Pfizer/BioNTech vaccine doses bought by the UK are produced in Belgium and a no-deal Brexit could result in import delays at Channel crossings. The UK government has a contingency plan to airlift vaccines into the country if necessary.

"Canada has bought enough coronavirus vaccine doses to vaccinate its population five times over"

Restrictions and measures

Places that have effectively eliminated the virus, such as New Zealand and some parts of Australia, have already been able to end almost all restrictions within their borders for long periods of time. They may decide to aim for herd immunity before relaxing all coronavirus-related border controls.

"We won't be out of this until we have a nation which has had a full vaccination programme," Australian health minister Greg Hunt said in November 2020.

Protecting an entire population – achieving herd immunity – might require vaccinating anywhere from 60 to 100 per cent of people depending on how effective the vaccines are at preventing severe disease and transmission. In countries that failed to contain the virus, the aim is to vaccinate the most vulnerable before easing restrictions. In the UK, this means vaccinating the 20 million people who are aged over 50, are at risk for other health reasons or work in healthcare or care homes. The hope is this could be done by spring.

In practice, many countries may decide to ease restrictions as soon as the number of people dying or in hospital with severe covid-19 begins to fall, even if case numbers remain high. This could start to happen once a significant proportion of older and vulnerable people have been vaccinated.

In the meantime, lockdowns are likely to continue to be part of life. And measures with minimal economic impact could

Nobody says purgatory is fun, but it does end. In the meantime, these are some of the big issues we face in the months ahead.

Vaccine roll-out

Now we have covid-19 vaccines that seem to work, the conversation has turned to who will get a vaccine, and when. A huge challenge will be ensuring that poorer countries can access doses.

In 67 low and lower-middle income countries, nine out of 10 people are set to miss out on a vaccine this year, according to an analysis from the People's Vaccine Alliance, a coalition spearheaded by Oxfam.

High-income countries have already snapped up more than half of the total of around 8 billion doses of vaccines that have been allotted to date. If these were evenly distributed, it would be enough to immunise more than half the world's population, given that most of the vaccines in development require two doses.

The UK has pre-ordered 357 million doses of vaccines from seven developers, all at various stages of development. If they were all green-lit, and all needed two doses, this would be more than enough to immunise

continue well into 2021. Lynne Williams, a psychologist at the University of Strathclyde, says that vaccination should be thought of as just one of many layers of defence that we will need to use for at least the next six months. The others include handwashing, mask wearing and social distancing. This is becoming known as the Swiss cheese model of pandemic defence: each layer has holes, but stack them up and it is much harder for a virus to sneak through.

How long immunity lasts

As vaccine trials only began a few months ago and this coronavirus is new to humankind, we don't know how long immunity lasts, whether from infection or from a vaccine. But it is a good sign that the number of people who have been infected twice seems to be small so far. "Immunity works most of the time," says Tim Cook at the University of Bristol, UK.

Studies of people infected with the virus suggest that while antibodies produced in response wane relatively quickly, measures of longer lasting immunity, such as levels of memory B-cells and T-cells, do persist for more than six months.

The initial protection from vaccination is likely to taper off over time, says Al Edwards at the University of Reading, UK. "The trouble is, we need to know how long that curve is," he says. As larger numbers of people are vaccinated, it is also possible that the virus will evolve and regular vaccinations will be required, like with seasonal flu.

Immunity passports

The question of immunity is intricately tied to the idea of vaccination certificates. Organisers of entertainment events, for instance, might enforce proof of vaccination to make sure the virus isn't spreading through the crowd. Airlines could do the same to try to prevent spread into



ARON CHOWN/PA WIRE/POOL VIA REUTERS

Unanswered questions

Back in March 2020, the World Health Organization (WHO) published a document setting out the known unknowns about the SARS-CoV-2 coronavirus and covid-19, which also served as a global road map for research. A spokesperson for the WHO told *New Scientist* that while good progress has been made so far, "urgent questions remain".

These include:

- The origin of the virus, and exactly how it spreads
- The strength and duration of naturally acquired immunity
- How best to treat people, and the development of highly effective treatments
- How to win public acceptance for restrictive control measures
- Development of low-cost, high-volume, rapid diagnostics for infection and immunity
- Making absolutely certain the vaccines really are as effective in the real world as they have been in trials

New questions have also arisen since March, especially around the long-term effects of the virus, and the evolution of new strains. Scientists will urgently seek to answer all these in 2021.



JACQUELYN MARTIN/POOL VIA REUTERS

Clockwise from top left: A card reminds people to get their second dose of vaccine in a London clinic

Arsenal fans social distance at a football match

Vaccination begins in the US last month



"In some countries, workplaces, schools, sports arenas or entertainment venues might demand proof of vaccination"

STUART MACFARLANE/ARSENAL FC VIA GETTY IMAGES

countries that have infection under control. Indeed, the CEO of Australian airline Qantas, Alan Joyce, has said he envisages this becoming necessary for all passengers on the airline's long haul flights.

The main problem with the idea is that we don't yet know how long a vaccine confers immunity for, nor whether it stops people from incubating the virus and passing it on.

Assuming that answers begin to emerge, it could be helpful for people to have certificates showing they have been vaccinated and when, as well as which product they received, as different vaccines may give different lengths of protection.

This wouldn't be unprecedented. Some countries require visitors to show evidence of vaccination against yellow fever on entry. And some hospitals require healthcare workers to have been vaccinated against hepatitis B, a blood-borne virus that causes liver disease.

Vaccines against those viruses aren't in short supply, however. So until everyone who wants a coronavirus vaccine has had one – which could take many years – placing restrictions on people who lack such a certificate would be impractical.

"I don't think [vaccination certificates] are as much of a new concept as they might appear," says Edwards. "But depending on what you want to do, it's greyer than it seems."

Mandatory vaccination

Many of us are eager to get vaccinated against covid-19. But what if you aren't? Will governments force you to do so?

"I think all of us who work in public health would rather avoid that as a means of getting people vaccinated," Michael Ryan of the WHO said at a briefing last month.

Policies worldwide are already diverging. For instance, President-elect Joe Biden has said people in the US won't be forced to have the vaccine. The UK has no plans to make it mandatory but hasn't ruled it out, while the state of São Paulo in Brazil has said coronavirus vaccination will be required by law. Australia already withholds some benefits from parents whose children don't receive vaccines for other illnesses.

Even where vaccination isn't required by governments, people might still end up feeling obliged to get vaccinated. For example, in some countries, workplaces, schools, sports arenas or entertainment venues might demand proof of vaccination. Care homes, in particular, might insist that workers and visitors have had a shot, as even if all residents have been vaccinated there is still a risk a few of them could get covid-19 because the vaccines are not 100 per cent effective.

Could health insurers refuse to pay for treatment if people who refuse vaccination develop covid-19? Lawrence Gostin at Georgetown University in Washington DC doesn't think so. "The fact that an individual refused a vaccine does not affect the legal obligations of the health insurer to pay covid-related treatment bills," he says. "I also think this is the ethically right decision."

Vaccine hesitancy

About a quarter of the UK population is hesitant about getting a covid-19 vaccine. A recent paper by Daniel Freeman at the University of Oxford and his colleagues shows that hesitancy covers a wide range of views. In a poll of 5000 UK adults,

6.1 per cent said they definitely wouldn't take a covid-19 vaccine, 5.7 per cent that they probably wouldn't, 12.7 per cent may or may not take it and 1.6 per cent don't know.

"What I find concerning is there's a substantial minority of people where there seems to be a divide with mainstream medical scientific opinion," says Freeman. For example, 1 in 5 people think safety and efficacy data has been made up. The two drivers for hesitancy seem to be the misplaced ideas that covid-19 is no worse than the flu, and that vaccine safety isn't established.

In the US, just half of adults say they will get vaccinated. Another quarter are unsure and the remaining quarter say they won't take it, according to a recent survey.

Patrick Vallance, the UK's chief scientific adviser, says hesitancy falls into several groups. "The vast majority of people want to get vaccination. There's then a group with a legitimate set of questions: how do I know it's safe, is it right for me? Many of the people labelled as vaccine hesitant actually just have a series of questions that need to be addressed," he says. "Then there's a third group, of anti-vaxxers, and you're never going to persuade them come what may, but they are a very, very small group."

Return to normality

After the first results showing the Pfizer/BioNTech vaccine to be effective, John Bell at the University of Oxford predicted "with some confidence" that life in the UK would return to normal by the spring. His view is a very optimistic one. Most think something resembling normality, with widespread social mixing in public places, homes and workplaces, will come later. Depending on vaccine supply, that will come later still in other parts of the world.

Even these forecasts may yet change. As Farrar tweeted on 19 December in response to the news of the new SARS-CoV-2 variant in the UK: "Since Jan2020 much of this pandemic has been very predictable... We may be entering a less predictable phase." ■

Signal Boost

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **Estuarine & Coastal Sciences Association**



ECSA promotes estuarine and coastal sciences, and celebrates its 50th anniversary in 2021. We are an international society and our mission is to promote and advance multidisciplinary research into all aspects of estuarine and coastal environments, and to support the application of science and technology for their sustainable environmental management. To achieve this our main aims are:

- To promote excellence in estuarine and coastal marine science, technology and management
- To focus on promoting young scientists and early-career academics
- To actively engage in global outreach with an emphasis on developing countries

We run science meetings at local and international scales to promote knowledge dissemination, and to provide young scientists with opportunities to present their work, and to network with more established scientists. We hope to have an international meeting in India in the next few years (recent ones have been in Australia, Germany and China).

A joint meeting with EMECS (the International Center for Environmental Management of Enclosed Coastal Seas) is due to be held in Hull, UK in September 2021 (for details see www.estuarinecoastalconference.com). We have run many workshops, and also produce handbooks and other publications. ECSA members, and members of ECSA Council, come from a wide range of academic, regulatory, consultancy and other backgrounds. The covid-19 crisis is likely to mean changes to how we all operate, and we are further developing our website to extend online communications and resources.

We are keen to encourage the next generation of scientists in a range of disciplines and career areas, particularly workers in developing countries. To do this we have a range of membership fees. We have a range of

awards to support members' attendance at our conferences. For our most recent international meeting in Australia we awarded 32 grants to cover travel and fees. We can support research work where individuals need small grants to support their work, for example enabling the purchase of sampling equipment.

We have a student/early career representative on ECSA Council, and are actively engaging with student members.

The world needs to address major threats to marine and coastal ecosystems – climate change, sea-level rise, ocean acidification, ecosystem shifts, plastic pollution, mineral resource exploitation, biodiversity loss and more. To help do this we need to share knowledge and ideas, and ECSA actively promotes this type of knowledge gathering and exchange. We all need to rise to the challenge.

Want to help?

Join the ECSA community to help understand and protect our coastal and estuarine ecosystems for a better world. To find out more, please visit ecsai.international

Space exploration



NASA's Perseverance rover fires its engines as it nears the Martian surface in this illustration

A swarm of spacecraft will arrive at Mars

Three missions to Mars could rewrite our understanding of the Red Planet's evolution, says **Leah Crane**

FOR Mars fans, February will be an exciting month. The Red Planet is getting three visitors from Earth, which all took off in July 2020. The Hope orbiter, the first Mars mission from the United Arab Emirates, was first to launch, followed by China's Tianwen-1 mission, which includes an orbiter, a lander and a rover. The last to take off was NASA's Perseverance rover.

Hope will be the first to arrive at Mars, skimming into orbit around 9 February. It will check its instruments and then start taking scientific measurements in May. The orbiter will observe the atmosphere, with a focus on how gases are able to escape and float away into space – the same process that took early Mars from a wet world with a thick atmosphere to the arid planet we see today.

"The Hope probe will be able to give us a unique perspective when it comes to the

Martian atmosphere, because it's the first mission that's been able to combine global coverage, different wavelengths and variation over time," says Hessa Al Matroushi, the mission's science and data analysis lead. "We're looking into the gaps in the understanding of the Martian atmosphere and trying to fill in those gaps."

Tianwen-1 will probably arrive next, although the exact date hasn't yet been announced. Once the spacecraft is in orbit,

"The Hope probe will be able to give us a unique perspective when it comes to the Martian atmosphere"

a landing pod will detach and head towards the surface. After it lands, a little ramp will slide out and the rover will unfurl its solar panels and wheel away.

The orbiter will help relay data from the rover back to Earth, but it also has its own instruments to observe Mars's atmosphere and surface. The rover carries a radar system to penetrate about 100 metres beneath the surface, instruments to analyse samples of Martian dust, a magnetic field detector and a set of cameras.

Perseverance will probably be the last of the three missions to arrive, reaching Mars on 18 February. The landing will look nearly identical to that of the Curiosity rover in 2012, with a key difference: a new navigation system that will take pictures as the rover nears the surface to let the lander's computer pick the safest spot to land.

"NASA has nicknamed it 'Neil Armstrong for Mars', because it uses cameras to image the landing site so it can divert away from dangerous targets," says Briony Horgan at Purdue University in Indiana. "That's what Neil Armstrong did on Apollo 11, because the landing site they had chosen turned out to be unsafe, so he had to look through this little window and find a new, safer landing site by eye."

This landing system means we don't know exactly where Perseverance will touch down. After it does reach the surface, though, the rover's prime directive is to collect and store samples to be picked up and returned to Earth by a planned later mission. Perseverance will also take its own samples to look for signs of ancient life. Researchers will be able to do more detailed studies on the samples that come back to Earth.

Although these three missions will reach Mars at about the same time, there isn't much that they can do to work together. "The three missions will be going to very different places and doing different things," says Horgan. "All of this data together will help us build a much better picture of the planet as a whole." ■



Leah Crane is New Scientist's space and physics reporter based in Chicago

Pollution

Just how harmful are these tiny pieces of plastic?

Our world is littered with microscopic plastic particles, and we will soon know if they are a health risk, says **Layal Liverpool**



Small fragments of plastic can break down even further when exposed to the environment

PC55609/GETTY IMAGES

DESPITE mounting evidence that we eat, drink and breathe microplastics, it still isn't clear whether these tiny particles get absorbed into our organs, tissues and cells and affect our health. In 2021, we will finally discover whether microplastic particles make it into our blood – the gateway to our organs and tissues – and, crucially, if they can infiltrate our cells.

"We're very, very close," says Juliette Legler at Utrecht University in the Netherlands. Legler is involved in two of four new research projects being funded by the European Commission that are investigating the impact of microplastics on human health. "I expect breakthroughs in the coming year for sure," she says.

Before we can understand how microplastics might affect health, we have to detect them in the first place. Most studies of microplastics have focused on particles in the micrometre range because these are easiest to find in experiments, says Legler. "But it's very clear that the smaller the plastic particle is, the easier it is to be taken into the cell and the greater the chance that there may be an adverse effect."

In particular, nano-sized particles may be able to cross the blood-brain barrier, one of the body's key defences, says Dick Vethaak at Deltares, a research institute in Delft, the Netherlands.

"We learned from decades of air pollution exposure that particle size can be one of the contributing factors to understanding the toxicity of air pollution, and I think – you know, this is my opinion and I don't have any evidence backing this up – but I think size is also going to be an important consideration for the microplastic particles as well," says Douglas Walker at the Icahn School of Medicine at Mount Sinai, New York.

Legler, Vethaak and Walker believe that advances in analytical chemistry and microscopy will give us the ability to detect these much tinier plastic particles

"In 2021, we will finally find out whether microplastic particles make it into our blood and infiltrate our cells"

in humans. In August last year, researchers at Arizona State University developed a method to detect and quantify both microplastic and nanoplastic fragments in human tissues and organs. With new techniques like this, we can expect to see a flurry of results in the coming months.

"There are a number of groups on the brink of publishing some very good data, very, very high-quality data," says Legler. Her research group has spent the past

year or so looking at microplastics in the placenta and investigating whether there are potential risks to a fetus in the uterus. It still isn't known whether microplastic particles can cross the placenta in humans.

"We'll be looking in the laboratory with human placenta, measuring human placenta samples," says Legler. "We have seen in animal studies that microplastics dosed directly to pregnant mice or rats will be taken up by the fetus."

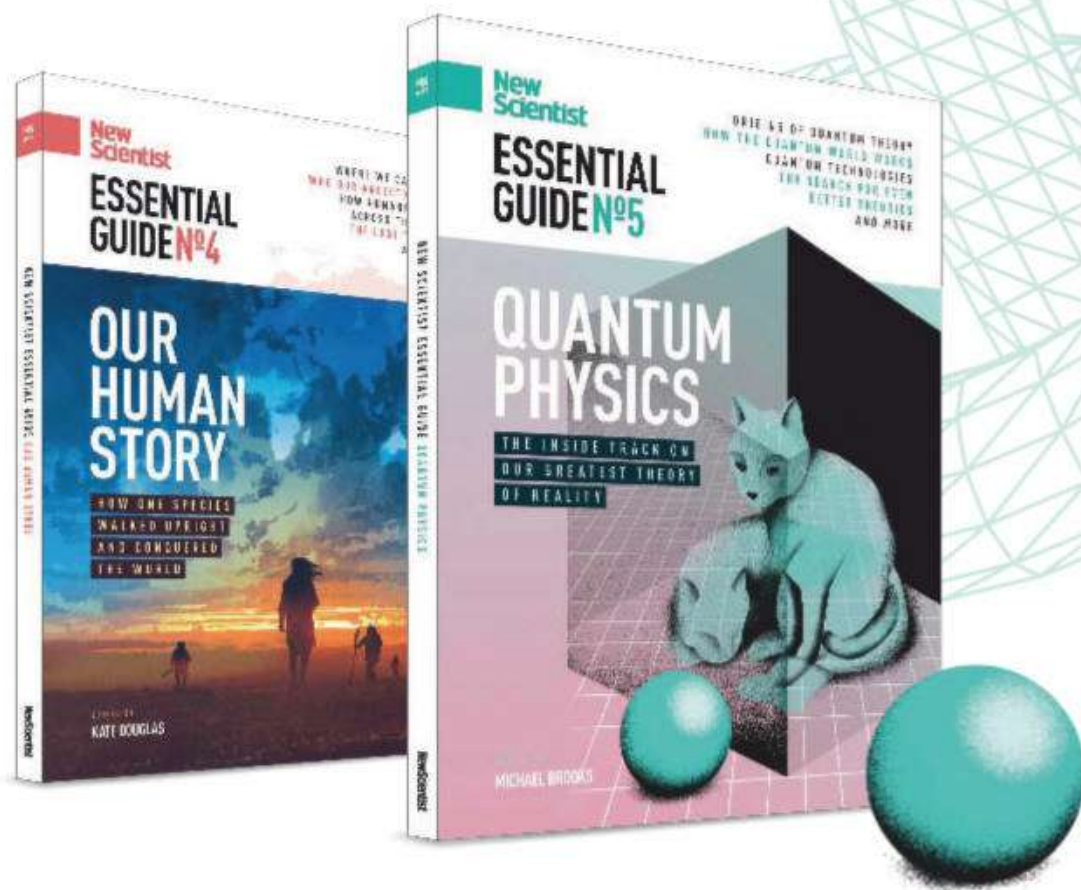
Her team is also discovering hints that microplastic particles may be capable of penetrating human placental cells grown in a dish in the laboratory. The next step will be to investigate how any exposure to microplastics affects the developing fetus.

Just the mechanical stress of having microplastic particles inside cells could be enough to cause damage, she says. But there are also concerns that microplastics could carry harmful microbes, such as viruses and bacteria, into our cells. "It's a very broad and complex area and I think we'll be learning a lot more over the next few years," says Walker. ■



Layal Liverpool is a *New Scientist* reporter based in Berlin

NewScientist ESSENTIAL GUIDES



NEW SCIENTIST ESSENTIAL GUIDES DELIVERED DIRECT TO YOUR DOOR

Based on the best coverage from *New Scientist*, the *Essential Guides* are comprehensive, need-to-know compendiums covering the most exciting themes in science and technology today.

Get the series, including the latest issue on Quantum Physics, with an *Essential Guides* subscription. It means you don't have to search for issues in the shops – we can deliver them direct to your door.

FOR MORE INFORMATION ON FUTURE ISSUES AND SUBSCRIPTION OFFERS, VISIT:
[NEWSCIENTIST.COM/ESSENTIALGUIDE](http://newscientist.com/essentialguide)

Global warming



A big year for climate action

A string of opportunities to confront the climate emergency will come like drumbeats in 2021, says **Adam Vaughan**

Members of the Extinction Rebellion environmental group protest in central London in September

LAST year was meant to be a blockbuster for action on the climate crisis. But the unexpected covid-19 pandemic upended climate choreography, postponing the major UN summit COP26 and forcing striking students off the streets. There are good reasons to think 2021 will be different.

Global carbon dioxide emissions fell an unprecedented 7 per cent in 2020 due to coronavirus restrictions, making a rebound in 2021 very likely, says Corinne Le Quéré at the University of East Anglia in the UK.

“What is more difficult to say is what the size of the rebound will be in 2021, whether it will come back to 2019 levels, or perhaps even higher,” says Le Quéré, who serves as an adviser to the UK and French governments. She expects the transport sector, which saw the steepest drops in emissions in 2020, will continue to be impacted this year as covid-19 restrictions remain for a time. “It’s a lot less certain what will happen

to the rest of the economy,” she says.

What happens to emissions hinges largely on the colour of governments’ stimulus packages as the pandemic recedes, be they green, with investments in renewable energy, or brown with money ploughed into fossil fuel projects. Le Quéré says green recovery plans could make a dent in 2021 emissions, such as policies encouraging more walking and cycling, but many environmental pay-offs from such plans will take longer to be noticeable, such as investments to support electric cars.

However, just 1 per cent of the stimulus announced worldwide is green so far, according to an analysis by Bloomberg New Energy Finance. “What we’re actually seeing is largely brown recovery programmes. That needs to change,” says Peter Betts at UK think tank Chatham House and the UK’s top climate negotiator until 2018. If a recovery plan that prioritised lower carbon emissions did come to pass, the UN

Environment Programme (UNEP) recently estimated it could cut the emissions we would see in 2030 by a whopping 25 per cent, compared with what they would be if we continue on our current track.

However 2021 pans out, one year is almost certainly not enough time to change trajectory and dodge the catastrophic warming that leaders agreed to try to avoid under the Paris Agreement. That is why ahead of COP26, which is now set to take place in November 2021, governments are due to submit more ambitious goals for carbon cuts by 2030, known as nationally determined contributions (NDCs). In addition, many are declaring longer-term goals to reach net-zero carbon emissions.

Last year ended with big emitters making a flurry of important pledges. In September, China said it would aim to be carbon neutral by 2060, followed by promises by Japan and South Korea to reach net zero by 2050. They were quickly followed by the UK and EU setting targets to cut emissions by 68 and 55 per cent by 2030, respectively. "I think the envelope of the possible has increased very sharply in the past couple of months," says Betts.

The US election result holds major ramifications for the climate. President-elect Joe Biden has said he will immediately reverse the country's exit from the Paris Agreement when he is inaugurated on

"The envelope of the possible has increased very sharply in the past couple of months"

20 January, meaning the US should be formally back in the accord within weeks. Far more important will be a new NDC for the US, which is likely to take months to draw up. Biden also indicated he will adopt a 2050 net-zero goal. If that happens, it would mean countries responsible for 63 per cent of global emissions have a net-zero plan, up from 51 per cent now, according to UNEP.

Bill Hare at Climate Action Tracker (CAT), which analyses national climate targets, says the situation as we enter 2021 is a mixed bag. "There is a big gap between



Renewable energy, like that made by wind turbines in Jiangsu, China, is key to decarbonising the world's economies

TPG/GETTY IMAGES

promising to do net zero and promising to do something in the short run," he says.

If achieved, the recent net-zero goals could hold the global temperature rise to 2.1°C by 2100, close to the Paris deal's upper limit of 2°C, CAT has found. The bad news is that the actual policies of governments, not targets, put Earth on track for more like 2.9°C of warming. Fortunately, Hare says new short-term targets could drive more real action: "In the next 12 months, we should see quite a lot of countries come up with much better 2030 goals."

Extreme weather

Throughout 2021, the US, China and EU will be pivotal in international climate talks and geopolitics, says Richard Black at the Energy & Climate Intelligence Unit, a UK think tank. China's revised NDC is expected soon, and a "low ball" one would be disappointing, says Betts.

Feeding into these international efforts will be a mix of science, activism and any highly destructive extreme weather-related events akin to 2020's wildfires in Australia and the US. The UN's Intergovernmental Panel on Climate Change was due to publish three reports this year. One on how to slow climate change and another on how to adapt to it are likely to be delayed to 2022 due to covid-19. However, one on the physical science of climate change should be published around July, early enough to influence negotiators at COP26. "It will show the evidence is even stronger: even more confidence about it being real and human-caused," says Richard Betts at the Met Office in the UK.

2020 was on track to be the warmest or second warmest year on record, despite the cooling effect of the current La Niña weather pattern, which should continue until the northern hemisphere spring. The UK's Met Office forecasts that 2021 will be 0.91-1.15°C warmer than pre-industrial temperatures, making it unlikely to break records.

Key climate action events will come like drumbeats through 2021. The postponed UN biodiversity summit is now scheduled for May in China, and is expected to touch on natural ways to mitigate climate change, such as tree planting. The G20 and G7 summits of leading economies will be important, with Italy and the UK holding the respective presidencies, and both countries co-organising COP26. Meanwhile, the Commonwealth Heads of Government Meeting on 21 June will be a chance for the UK to "make common cause" with countries vulnerable to climate change, says Black.

How much pressure citizens put on their governments will influence the outcome of COP26, and therefore how dangerously hot the world will get this century. The Fridays for Future youth climate movement inspired by Greta Thunberg "could be very important" in 2021, says Black, though he thinks Extinction Rebellion is "probably on the way out as a force". Health and faith groups could play a key role too, he adds. "What is needed is much more pressure from civil society," says Hare. ■



Adam Vaughan is chief reporter at *New Scientist* and is based in our London office

**NOW
ON SALE**

COURSE TWO:

HOW YOUR BRAIN WORKS

AND HOW TO MAKE THE MOST OF IT

Are you keen to learn more about what you are carrying around upstairs? Now you can get the lowdown on the mysteries of the human brain from world-class scientists and experts with *New Scientist Academy*.



Topics covered include:

- The complexity of the human brain and the key structures that make it so special
- How the brain processes information, creating thoughts, memories and a conscious reality
 - The power of the unconscious mind and how to harness it
 - How to keep your brain working better for longer

**New
Scientist
Academy**

NOW ON SALE

Visit newscientist.com/courses

The columnist
James Wong on
the truth about
raw food diets **p20**

Letters
This magazine
saved me from
creationist views **p22**

Culture
Forward-thinking
books on health, tech,
climate and more **p24**

Culture
Ten top sci-fi novels
to look forward
to in 2021 **p25**

Aperture
Mapping the hidden
phenomena of
Antarctica **p28**

Comment

Fatigued by tech

The coronavirus pandemic has had us glued to our devices, but there are easy ways to reach a better balance, says **Becca Caddy**

IN RECENT years, many of us have made concerted efforts to reduce the amount of time we spend using our devices. A 2019 study found that one in four people had made changes to how they use their tech by deleting apps, reducing notifications and consciously cutting down the time they spend on social networks. Then the coronavirus pandemic happened – and for many, such practices went out the window.

In one survey, 46 per cent of people said they had increased their smartphone use throughout 2020. According to another, internet users in the UK spent an average of 4 hours online each day in April 2020 compared with 3.5 hours in September 2019. As expected, as our in-person interactions went down, the time we spent on screens went up.

The relationship between tech and mental health is a tricky one and far more nuanced than attention-grabbing headlines might have us believe. However, a growing body of evidence suggests possible links between the amount of time we spend on social media and a negative impact on our well-being.

Many apps are designed to grab our attention and not let go for as long as possible. “Like” buttons, bright red notifications and never-ending news feeds all help keep us fixated and employ similar methods to gambling tech. Scrolling to refresh is like pulling down the arm on a slot machine, and because the potential for new



“rewards” is unpredictable, we keep pulling just in case.

For most people, the answer to this issue isn’t a digital detox: deleting as many apps as you can or cutting yourself off from your devices. Instead, balance is what will help avoid tech overload, and there are numerous ways that we can make that easier for ourselves.

Your phone’s built-in tracking features or apps like Moment can help you keep tabs on the hours you spend using tech. This allows you to see clearly whether you actually spend a lot of time on

your devices or whether it just feels like you do – studies have shown that we are notoriously bad at estimating how long we spend looking at screens.

Some apps, such as Forest, can help you focus by visualising a virtual tree that only grows when you have streaks of time working, not scrolling. Others temporarily block enticing apps so you don’t fall into endless scroll-holes, which is a lot easier than constantly deleting and redownloading your favourite apps.

You should also turn off or limit

push notifications. Studies show that if you look at your phone when you get a new notification, you are likely to check other things too. These are called within-phone interruptions and you can lose huge chunks of your day to them. One estimate suggests that when a task is interrupted by push notifications, it can end up taking four times longer to complete than it would do otherwise.

I also recommend moving your phone away when you need to focus or spend time with others. You have probably heard this advice before, but here’s why it is important: a 2017 study found that the mere presence of your phone can be distracting, even when it isn’t in your line of sight.

Ditching social media or your devices altogether was once a fashionable piece of advice, but not only is it unsustainable for most of us, it isn’t advisable either. Technology helps many of us manage our emotions – by using games to dispel tension, for instance, or social media to combat loneliness. As much as tech can be a source of stress, in a time when the world feels more difficult to navigate than usual, it can also be a much-needed source of relief, joy and connection. ■



Becca Caddy is the author of *Screen Time: How to make peace with your devices and find your tech equilibrium*

#FactsMatter

Are there benefits to a raw-food diet? Eating predominantly uncooked food is a fad that goes way back, but not one we need to follow, writes **James Wong**



James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

James's week

What I'm reading

Potted History by Catherine Horwood. *Yes, it is about houseplants. Yes, I am that predictable.*

What I'm watching

The new season of How To Get Away With Murder on Netflix. *Always good to have some tips.*

What I'm working on

I have just finished two new BBC documentaries on the future of farming.

This column appears monthly. Up next week: Chanda Prescod-Weinstein

DIETARY fads come and go, but perhaps the most enduring of them all is the raw-food movement. It dates back to at least the mid-1800s when US Presbyterian minister Sylvester Graham claimed that people would never become ill if they only ate uncooked foods. The idea that cooking degrades the natural nutrition inherent in foods can seem intuitively plausible. But is it true?

Perhaps the first curious thing you notice when delving through academic journals that have covered this topic is that, although there has been plenty of research on raw-food diets, especially in recent years, almost all of the content is about cat and dog food. When it comes to human studies, there are really only a few papers to date, often using different designs and measures, making for quite a patchy evidence base.

One 2005 study found that followers of predominantly raw-food diets did indeed have lower cholesterol and triglyceride levels, which are key risk factors for cardiovascular disease. This is unsurprising, given that diets high in fruit and vegetables are linked to better heart health, and the participants were eating a whopping 20 servings a day on average. On the other hand, the same study also discovered that participants were often deficient in vitamin B12, a nutrient found almost exclusively in animal products in nature.

Another study in the same year found similarly mixed results. While people on a raw-food diet tended to weigh less and be leaner than the general population, they also tended to have significantly lower bone density in clinically important skeletal regions. Although the authors were keen to point out the small size of their

study, they concluded that this low density was probably due to bone loss coinciding with the adoption of the low-calorie, low-protein, raw-food lifestyle.

But what about other health impacts? In one study from 1999, followers of this diet were found to have much higher rates of erosion of tooth enamel, with only 2.3 per cent of the group showing no signs of this. The erosion rate was almost six times that of the control group. This was blamed on the large amounts of acid coming from their high fruit consumption. When researchers looked into the levels of carotenes

“The advent of cooking could have been what allowed humans to develop larger brains”

in the blood of followers of this diet, they found that these plant-derived, antioxidant compounds were either only at normal (and sometimes low) levels, despite the high amounts found in this diet. This was attributed to very low fat consumption, which traditionally acts as a delivery mechanism for such oil-soluble antioxidants to be absorbed by our bodies.

This highlights a critical sticking point in answering the question of health benefits associated with raw-food diets. People following them often have several other notable dietary factors that can affect the results. Most proponents of raw-food diets, for example, are also vegetarian or vegan. They additionally often consume very low levels of starchy carbohydrates – no bread, rice and pasta. In a very real sense, the defining feature of raw-food diets isn't so much the rawness of their ingredients, but the substitution

of entire food groups for fruit and vegetables.

This isn't without good reason either. Consuming many animal foods in an uncooked state carries a high risk of infection with potentially life-threatening parasites and microbes, which cooking renders safe.

Humans also don't produce the right digestive enzymes or harbour the necessary gut flora to access the calories in uncooked carbohydrates either, which is why we have spent inordinate amounts of effort for millennia cooking a lot of our food. This can render toxic foods safe and tasty, and allows us to access calories that are off limits to our species without it.

Even when it comes to plants that are perfectly safe to eat raw, such as tomatoes, cooking breaks open their tough cell walls, allowing significantly improved access to the nutrients within. With crops like kale and spinach, cooking reduces their volume and removes difficult-to-digest compounds, allowing us to consume a much larger amount of them. In fact, many evolutionary anthropologists suggest it was the advent of cooking that triggered the reduction in gut size that allowed us to develop larger brains, which distinguishes our species from our ancestors.

While not a science point, a raw-food diet also doesn't sound like much fun. Perhaps it is relevant to flag up that Graham believed that the suppression of pleasure in many forms was essential to health, recommending only cold baths and sleeping on hard mattresses among other things.

Raw food can, of course, be a healthy choice, but cooking food isn't just an ideal way of getting a varied, balanced diet, it is probably what made us human. ■

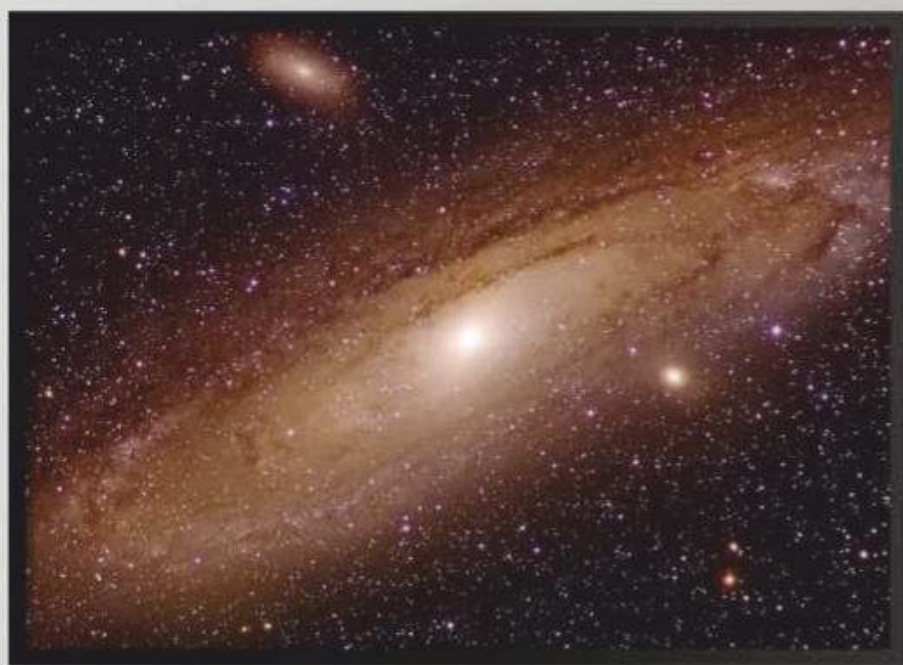


SPECTACULAR WALL ART FROM ASTROPHOTOGRAPHER CHRIS BAKER

Available as Acrylic, Framed & Backlit
or Fine Art Prints. All Limited Edition

www.galaxyonglass.com

chris@galaxyonglass.com | +44 (0) 7814 181647



THANK YOU!

To the many New Scientist readers from all over the world who purchased my art in 2020 I want to say a big Thank You! Here's an offer for all readers - use the code **newscientist** at check-out for a unique **10% discount** throughout January! Happy New Year from Chris Baker.

Editor's pick

This magazine saved me from creationist views

5 December 2020, p 26

From Linda Phillips,

Narrogin, Western Australia

Having read the tribute you published, I am reflecting on the death of Bernard Dixon, editor of *New Scientist* from 1969 to 1979. I started reading *New Scientist* as a very young child in the 1960s, and I well remember the improvements made by Dixon in the early 70s.

It is no exaggeration to say that the magazine changed my life for the better. In childhood, I was exposed to fringe religious views and my brain juggled creationist ideas against the science I read each week in the library. I am glad to say your magazine won out and helped me see the world as it really is, so my heartfelt thanks go to Dixon and *New Scientist*.

Time to get naked on the space station?

5 December 2020, p 17

Guy Cox, St Albans,

New South Wales, Australia

Your report on work to develop the first laundry detergent for use in space implies that International Space Station crew members are expected to wear their clothes until they are quite unpleasant. But why wear clothes at all during regular duties inside the station? The climate is controlled and there is no risk of sunburn.

The domestic cat isn't the only villain

31 October 2020, p 42

From Kevin D. Scott,

Calw-Ernstmühl, Germany

Although I don't consider myself to be a domestic cat lover, I feel they are being unfairly accused of decimating British wildlife, particularly birds.

I am not disputing that birds are killed by cats, but remember that many birds are killed during the migrating season every year when

their flight paths take them over France, Spain, Cyprus, Sardinia and Sicily. There, birds are often caught in nets and ultimately land on "gourmet" plates in restaurants.

The Thai wai may have helped contain the virus

28 November 2020, p 14

From Steve Coleman,

Cherng Thalay, Thailand

Your article on mass testing to control covid-19 emphasises the importance of using multiple methods to keep it restrained, and highlights the success of certain Asian countries in doing this.

Living in Thailand, where the infection rates have been low, it seems likely to me that the use of the Thai wai greeting (which involves pressing your own palms together in a prayer-like fashion) instead of handshaking, hugging and kissing must be a contributing factor. I would be interested to see if there was any correlation between low infection rates and cultures with non-contact greetings.

Here's how to sail on an ocean of light waves

28 November 2020, Letters

From Charles Sawyer, Byron Bay, New South Wales, Australia

The "something obvious" Matthew Allan is missing in how to steer a solar-powered space vessel is the resultant force felt by an object when light reflects from it. If it uses a mirror set at a non-right angle to the light as a sail, the reflected photons will create an almost equal but opposite reaction, causing a net off-axis force.

From Alec Cawley,

Newbury, Berkshire, UK

An equivalent of solar sailing on the sea, into which the keel bites to allow the ship to tack upwind,

is gravity. The mathematics is more complicated, but sailing a spacecraft using solar wind and gravity is similar to sailing on wind and open ocean.

Why inventiveness and empathy arose together

5 December 2020, p 34

From Brian Horton, West

Launceston, Tasmania, Australia

Simon Baron-Cohen points out that about 100,000 years ago, a rise in empathy and in inventiveness occurred, and that the brain circuits involved in both "surprisingly" arose at about the same time. He notes that in each individual, one circuit tends to dominate, and that the genes for invention are related to those for autism and Asperger's.

Perhaps the co-evolution of empathy and invention isn't so surprising. The most useful people to have around inventing stuff also tend to have lower empathy, so may find it hard to survive in a tribal environment. They need others with high empathy to keep an eye on them and to make sure their inventiveness is appreciated by the rest of the tribe.

Therefore, we should expect that genes for empathy and genes for inventiveness will both increase together, although in different people within any group.

Searching for an explanation for long covid

31 October 2020, p 10

From Mark Spinney,

Haslemere, Surrey, UK

Further to your report on the prolonged problems that a coronavirus infection can cause, my wife was diagnosed with covid-19 in March 2020. She experienced a high temperature, sore throat, chest discomfort and

breathlessness. Interestingly, a nurse said the chest discomfort in the sternum (and possibly the sore throat too) was a symptom of acid reflux that she had seen in other covid-19 patients. She recommended an antacid, which quickly reduced the symptoms.

Since recovering, my wife has had a couple of reoccurrences of acid reflux and breathlessness. I don't believe this was due to reinfection and assume it must be long covid. It occurred to me that the coronavirus might behave like some other viruses that are able to hide from the immune system in certain tissues, only to break out and flare up again. Have studies been done to test this possibility?

There is still time to do the right thing for Lolita

28 November 2020, p 40

From Jennifer O'Connor, PETA

Foundation, Norfolk, Virginia, US

Thank you for your thoughtful piece about efforts to free the orca best known as Lolita from the cramped confines of the Miami Seaquarium. It is unimaginable for any of us to envision 50 years in lockdown, let alone in conditions that fail to meet our basic needs.

Given the longevity of the Southern Resident orca clan from which she was taken, there is still time for Lolita to have a life. Her long-lost family, including an orca believed to be her mother, is still swimming in the Puget Sound inlet where Lolita was captured.

The Miami Seaquarium must allow Lolita to retire to a seaside sanctuary where she could feel waves, hear wild pods and finally have some relief.

Why did they let an iconic telescope fall apart?

2 December 2020, online

From John Davies,

Lancaster, Lancashire, UK

I am furious at the collapse of the Arecibo telescope. How was this allowed to happen? Puerto Rico is an unincorporated territory of the US, not of a low-income nation. ■



Want to get in touch?

Send letters to letters@newscientist.com;

see terms at [newscientist.com/letters](https://www.newscientist.com/letters)

Letters sent to *New Scientist*, 25 Bedford Street, London WC2E 9ES will be delayed

**New
Scientist**
Events



BIG THINKERS SERIES

Renowned for their bold vision and daring ideas, today's greatest minds in science discuss research that will transform our world.

**THE END OF AGEING
WITH AUBREY DE GREY**
21 January 2021
6-7pm GMT / on-demand

**THE SEARCH FOR
EXTRATERRESTRIAL LIFE
WITH AVI LOEB**
Thursday 11 February
6-7pm GMT / on-demand

**QUANTUM COMPUTING
WITH MICHELLE SIMMONS
AND JOHN MARTINIS**
Thursday 11 March
6-7pm GMT / on-demand

**PALAEONTOLOGY
WITH ELLA AL SHAMALI**
Thursday 25 March
6-7pm GMT / on-demand

**ORIGINS OF LIFE
WITH SEAN B CARROLL**
Thursday 22 April
6-7pm GMT / on-demand

**ARTIFICIAL INTELLIGENCE
WITH SUSAN SCHNEIDER**
Thursday 20 May
6-7pm GMT / on-demand

**CONSCIOUSNESS
WITH ANIL SETH**
September (TBC)
6-7pm GMT / on-demand

More to be
confirmed
shortly

Early booking tickets £13 or purchase a series ticket to all lectures and save £50.

To find out more and register visit newscientist.com/bigthinkers

Books to save the planet

To give Earth a lifeline, we need to upend many established ideas. Get stuck in for a bumper year of rethinking, say **Liz Else** and **Simon Ings**

Saving the planet

FOR good reason, this year is billed as the year we must come together to save human civilisation.

Fortunately, the technology needed to achieve a zero-carbon economy is surprisingly straightforward. Less easy is getting some 8 billion cantankerous primates to agree on a single course of action.

Help is at hand from a wide array of books. The first up is from Mike Berners-Lee of the Institute for Social Futures at Lancaster University, UK. He finds himself already having to update his 2019 bestseller, *There is No Planet B: A handbook for the make or break years*. Once again, he emphasises what we can do as individuals to address climate change, from eating less meat to preserving biodiversity in our own backyards.

Fair enough, although as Michael Mann argues in *The New Climate War: The fight to take back our planet* (reviewed next week), we should be suspicious of attempts to push responsibility for change onto citizens and away from the industries that are damaging our planet the most.

“AI research treats information as an extractive industry, taking us towards increased inequality”

Under a White Sky by Elizabeth Kolbert points out that many of our interventions in nature have been devastating and asks if it is too late for us to turn it around.

There is a balance to be struck here, and Bill Gates’s *How to Avoid a Climate Disaster* finds it. There are fortunes to be made in the new economy, but only if the right incentives are in place – and these

incentives will need political backing if they are to succeed.

We need to educate ourselves if we are to keep our governments, our employers and ourselves accountable in this crucial enterprise.

Thinking big

The year 2021 also promises to be the year in which we begin to reframe our place in the world, treating it as a system to be explored, rather than as an object to be exploited.

There are a number of threads here, from University of Oxford theoretical physicist Chiara Marletto’s revolutionary recasting of physics, *The Science of Can and Can’t*, to neuroscientist Anil Seth’s new theory of consciousness, *Being You: The inside story of your inner universe*. Seth encourages us to view ourselves as less apart from the rest of nature. Marletto’s contributions to “constructor theory” reconcile what we think of as physical laws with the open-ended possibilities thrown up by biology and information theory. It is a paradigm that, for all its rigour, re-enchants the world and enriches our place in it.

Alas, a lot of recent thinking has been leading us in the opposite direction. In her *Atlas of AI*, Kate Crawford at Microsoft Research blows the whistle on a field that, for all its millennial promise, treats information as just another extractive industry, so that we slide ever further towards undemocratic governance and increased inequality.

For a positive vision of the intellect set free, turn to Italian theoretical physicist and bestselling author Carlo Rovelli. His latest book, *Helgoland*, begins with 23-year-old Werner Heisenberg’s visit to the small,



DEEPLY BY PLAINPICTURE/VASILY PINDYURIN

What kind of future are we facing, and how should we think about it?

eponymous, treeless island in the North Sea, and the days he spent constructing one of the most transformative concepts in physics: quantum theory. By Rovelli’s closing pages, we find ourselves tearing across a universe made, not of particles, but of the relations between them. Heady stuff indeed.

Everyday science

The more we understand the world, the more magical it becomes, and this is as good a reason as any to join chemist and YouTuber Mai Thi Nguyen-Kim and enjoy some *Chemistry for Breakfast*, a romp through everyday science, from the moment the alarm clock disrupts

your exquisitely tuned biological clock to the physiological effects of that end-of-day tippie.

Several books this year explore the evolutionary underpinnings of such everyday moments. For example, we know how crucial cooking was to our evolution. Now, in *Delicious*, biologists Rob Dunn and Monica Sanchez ask what that earliest food tasted like, and whether, even as fruits were evolving to become tastier and more fatty, their very tastiness was driving some giant mammals to extinction.

Those seeking a deeper dive into human physiology will learn how their lives are influenced by their brain chemicals in radio presenter Ginny Smith’s *Overloaded*. Then there is *Ouch* by sociologist Margee Kerr and journalist Linda Rodriguez McRobbie,



a remarkably painless foray into a world of pain: why it hurts, why it doesn't always have to and why we sometimes crave it.

Our social behaviours also come under the magnifying glass this year, never more closely than in forensic criminologist Jane Monckton Smith's *In Control*, an analysis of domestic violence and murder. Smith has identified a timeline for how behaviour escalates until "crimes of passion" occur, and her work is already saving lives.

On a more cheerful, but no less profound, note, palaeoanthropologist Ella Al-Shamahi's *The Handshake* reintroduces us, after a year of social distancing, to that most ancient signal of sociability. The handshake is a gesture we share with chimps; no wonder doing without it has felt so alienating.

Looking for other worlds

If Earth's humans proved too much last year, maybe it is time to look elsewhere. Starting with the off-planet, there is *Extraterrestrial* by Avi Loeb, the Harvard University astrophysicist who caused a storm when he argued that the strange interstellar object – now named 'Oumuamua – first seen in our inner solar system in 2017 was an artefact created by an alien civilisation. Here, he outlines his arguments, urging us to keep our minds open. Some scientists are sceptical; others, like physicist Sean Carroll, think it is vital to be open to "audacious possibilities".

Another exciting option closer to home is to follow marine biologist Helen Scales into *The Brilliant Abyss*. The deep ocean is an extraordinary world in which luminescent creatures swim, vast quantities of carbon that would otherwise poison our atmosphere are trapped and strange bacteria that may hold promise for potent medicines are in abundance.

But it is also a looming battleground because of the huge mineral riches and the growing impact of pollutants and overfishing. Her book is both a revelation and a wake-up call.

The inside track

Four new books for 2021 from *New Scientist* consultants, staff and columnists put a bold spin on the future, past and present.

First is a thought experiment: how would you spend \$1 trillion on science in a year? Would you eradicate malaria, end global poverty, settle on the moon, solve climate change? In *How to Spend a Trillion Dollars*, Rowan Hooper, *New Scientist's* podcast editor, helps readers go on a spending spree for the global good. And ➤

Sci-fi: 10 top reads for 2021



Remote Control

Nnedi Okorafor (Tor.com)

Sankofa was just a girl until she became Death. Now she and her fox companion search the world for answers about what created her. Out January

The Expert System's Champion

Adrian Tchaikovsky (Tor.com)

In the sequel to *The Expert System's Brother*, Handry (a monster-fighting wanderer) acquires a band of fellow travellers just in time to face a new foe. Out January



The Galaxy, and the Ground Within

Becky Chambers (Hodder & Stoughton)

The Hugo award-winning finale of the epic *Wayfarers* series is a tale of expansion into the galaxy. Out February

We Shall Sing a Song Into the Deep

Andrew Kelly Stewart (Tor.com)

A choir of young boys live in a sub that patrols a drowned Earth in search of a religious cult. Sci-fi legend Kim Stanley Robinson is a fan. Out March

Unity

Elly Bangs (Tachyon Publications)

Another book that starts

underwater – but it turns into a *Mad Max*-style chase across the post-apocalyptic US, exploring identity and our sense of self. Out April

Fugitive Telemetry

Martha Wells (Tor.com)

The beloved *Terminator*-with-teen-ennui is back in book six of the *Murderbot* series. First catch up with the previous five. You won't be sorry. Out April

A Master of Djinn

P. Djèlí Clark (Tor.com)

Clark is to Cairo as Neil Gaiman is to London, exploring its magical, steampunk underbelly through special investigator Fatma el-Sha'arawi. Out May



The Ninth Metal

Benjamin Percy (HMH Books)

When a meteor shower rains a new and powerful metal onto Earth, the US Midwest erupts in a "gold rush" and nothing is ever the same again. Out June

Losing Gravity

Kameron Hurley (Saga Press)

Described as *Killing Eve* meets *Die Hard*, in space. What more could you want? Out TBC

The 22 Murders of Madison May

Max Barry (Hodder & Stoughton)

Just when you thought the multiverse had exhausted every plot, here is Max Barry's thought experiment: what if a serial killer could move between universes and kill the same person over and over again? Out July

The best films and TV



There is a lot to look forward to this year, and some may even be available as scheduled.

The release of **A Quiet Place Part II** (pictured above) has been delayed twice due to the pandemic, but perhaps this will fuel anticipation. The dystopian horror, starring Emily Blunt and written/directed by her husband John Krasinski, is now due for release in April 2021. The Abbott family live in an apocalyptic landscape plagued by monsters that hunt by sound, and they are about to discover there are other dangers out there too.

Bios, also pushed back from 2020 and due out in April, stars Tom Hanks as the ailing creator of a robot intended to care for his beloved dog after he dies, in an American Midwest destroyed by a cataclysmic solar event.

It isn't all sci-fi dystopias. Tom Cruise will be defying the laws of physics in **Top Gun: Maverick**, a long-awaited sequel to the 1986 classic. It is set for release in July.

A few months later, in October, Denis Villeneuve's much anticipated **Dune**, the second film adaptation of Frank Herbert's bestselling novel about feudal interstellar society, is due out.

Come December, **Don't Look Up** is set to be one of the

biggest ever Netflix films, starring Leonardo DiCaprio and Jennifer Lawrence as astronomers trying to warn the world about a giant meteorite heading towards Earth as a fumbling president downplays the dangers. It is being filmed in socially distanced conditions in Boston, and the cast includes Timothée Chalamet, Cate Blanchett, Meryl Streep and Jonah Hill.

Also out in December is **Babylon**, a new film from *La La Land* director Damien Chazelle. It takes a fresh look at how cinematic technologies have changed, examining the transition from the silent movie era to the talkies.

On the small screen, there is a smattering of prestige reruns of David Attenborough's series, plus other nature/climate change documentaries, including **I Am Greta**, about climate change activist Greta Thunberg. This had a brief cinema release but will air on the BBC in January.

Hawking, a new documentary from Sky (release date not yet available) aims to shed new light on the life of the late physicist through previously unseen private family archives.

Francesca Steele is a film and TV critic based in London

remember, \$1 trillion is less than the current valuation of Apple.

Equally challenging is *The Disordered Cosmos* by *New Scientist* columnist Chanda Prescod-Weinstein. Sharing a love of particle physics and dark matter, it comes with a strong political backdrop that calls on us to recognise that science, like most fields, is rife with racism, sexism and other dehumanising systems. It also encourages us to dream of a world predicated on the idea that we all have a fundamental right to experience and understand the wonders of the universe.

The stories behind *Four Lost Cities* by *New Scientist* columnist Annalee Newitz show the importance of the deep history of urban life for our near future. Newitz explores the rise and fall of Çatalhöyük in central Turkey, the Roman city Pompeii on Italy's southern coast, the medieval megacity Angkor in Cambodia and Cahokia, near modern St Louis, Missouri.

Could mathematics be the forgotten ingredient in the building of human civilisations? *The Art of More* by *New Scientist* consultant Michael Brooks reveals how we learned to imagine the things that we now call numbers and invented arithmetic, giving birth to money, trade and the vast majority of civilisation.

At school, many of us wondered about the point of geometry, calculus and algebra. Brooks shows how the childhood question "What's the point of this?" can be reframed: esoteric concepts such as imaginary numbers, cryptography and the semi-mystical digits of pi are revealed to be the essential building blocks of the 21st century.

Rethinking medicine

What does it mean to rebuild people through gene editing or other medical interventions? *CRISPR People* by Henry T. Greely, an ethics and law professor at Stanford University in California, dives in at the deep end with the

story of non-identical twin girls who were born in 2018 in China with their DNA edited as embryos.

For Greely, the experiment by Chinese scientist He Jiankui that enabled this was reckless and illegal, using technologies that have no extra benefits over existing ones, and is something we should ponder carefully.

Few can have given more thought to the ethics around this field than Jennifer Doudna, who, with collaborator Emmanuelle Charpentier, won the 2020 Nobel prize in chemistry for discovering CRISPR-mediated gene-editing.

Doudna's story is told in *The Code Breaker* by Walter Isaacson. It is a gripping tale, showing how our new ability to hack evolution will soon start throwing us

"Could mathematics be the forgotten ingredient in the building of human civilisations?"

curveballs. Should we, for example, use it to make us less susceptible to viruses? This is the kind of stuff that might well keep Doudna up at night.

Ethical questions of a different sort face Leana Wen, emergency doctor and health commissioner for Baltimore, Maryland, who has been named one of *Time*'s 100 most influential people.

In *Public Health Saved Your Life Today*, Wen gives an insider's account of the crucial role of public health in everyday medicine, from opioid addiction to the covid-19 pandemic. Her book's title comes from a phrase she uses a lot: "Public health saved your life today – you just don't know it."

Wen shows how public health weaves together advocacy, medicine and politics, pulling off the trick of creating programmes that treat gun violence as a contagious disease or pose racism as a health issue. Public health, she writes, means citizens don't die too early, and postcodes don't determine whether they live. ■

Positions for research in synchrotron and neutron imaging in hard materials and life sciences - in Denmark

Why us?

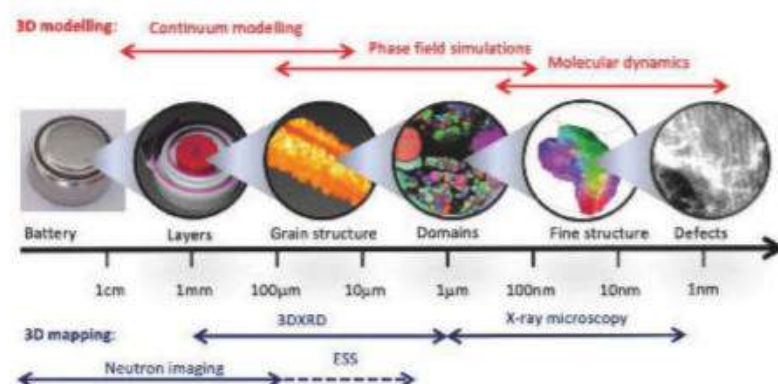
SOLID is a Danish Centre of Excellence with more than 40 scientists and engineers, who couple materials and health science research with developments in 3D synchrotron and neutron imaging. We work together in a dynamic, friendly team, to solve questions of relevance for energy, health and climate.

We are interdisciplinary, international and inclusive. Our environment is diverse, and dynamic. Motivated candidates are encouraged to apply, regardless of background.

Read more about SOLID at www.solid.dtu.dk

Our vision

We aim to visualize the internal structure of all sorts of solid materials, their creation and change during use - in 3D, on all the relevant length and time scales. This means we can generate and apply a new generation of more realistic multiscale material models. This would be a fundamental “game changer” in materials science, because effective models are the door to the dream of computational materials design. Multiscale 3D description is the key to understanding the basics of bone and tooth biology and thus for the development of new drugs and diagnostic methods, e.g. for osteoporosis. Similarly, our new high throughput 3D imaging methods will facilitate massive digitization of fossils and museum specimens, to facilitate progress in understanding human evolution and climate change



Why Denmark?

English is spoken widely and is the working language in the university. Denmark offers an attractive work-life balance, with work hard/play hard expectations. Research benefits from a deep culture of teamwork, creativity and enthusiasm in solving problems together, where students work side by side with senior scientists.

Denmark has a thriving food scene, excellent museums and infrastructure, beautiful natural scenery and friendly people. All of the SOLID partner institutions are in student rich cities. A young population means many cultural and athletic activities and music festivals.

The positions

As a cross disciplinary centre, we seek candidates with a background in physics, chemistry, biology, mathematics, materials science, geology or engineering. For the PhD positions, no specific experience is required in the topic of the research but keen interest and a drive for solving problems are essential. We also expect you to be strong in physics, chemistry and mathematics.

Our expectations about you, as a person

You are excited about fundamental science and applying the results to solve practical problems of importance to society. We expect that you enjoy being part of a team, that you have a sense of humour, you are a good problem solver, enjoy helping others and that you are also able to work effectively and independently.

We hope to receive your application

We plan to hire 7 PhDs and 3 postdoctoral fellows within the next half year. The openings are listed below but we are open to letters of interest at any time and for future positions. To learn more about the materials, projects and people, and to start your application, we refer to the homepage: www.solid.dtu.dk

PhD: High pressure neutron and x-ray studies of liquid structure

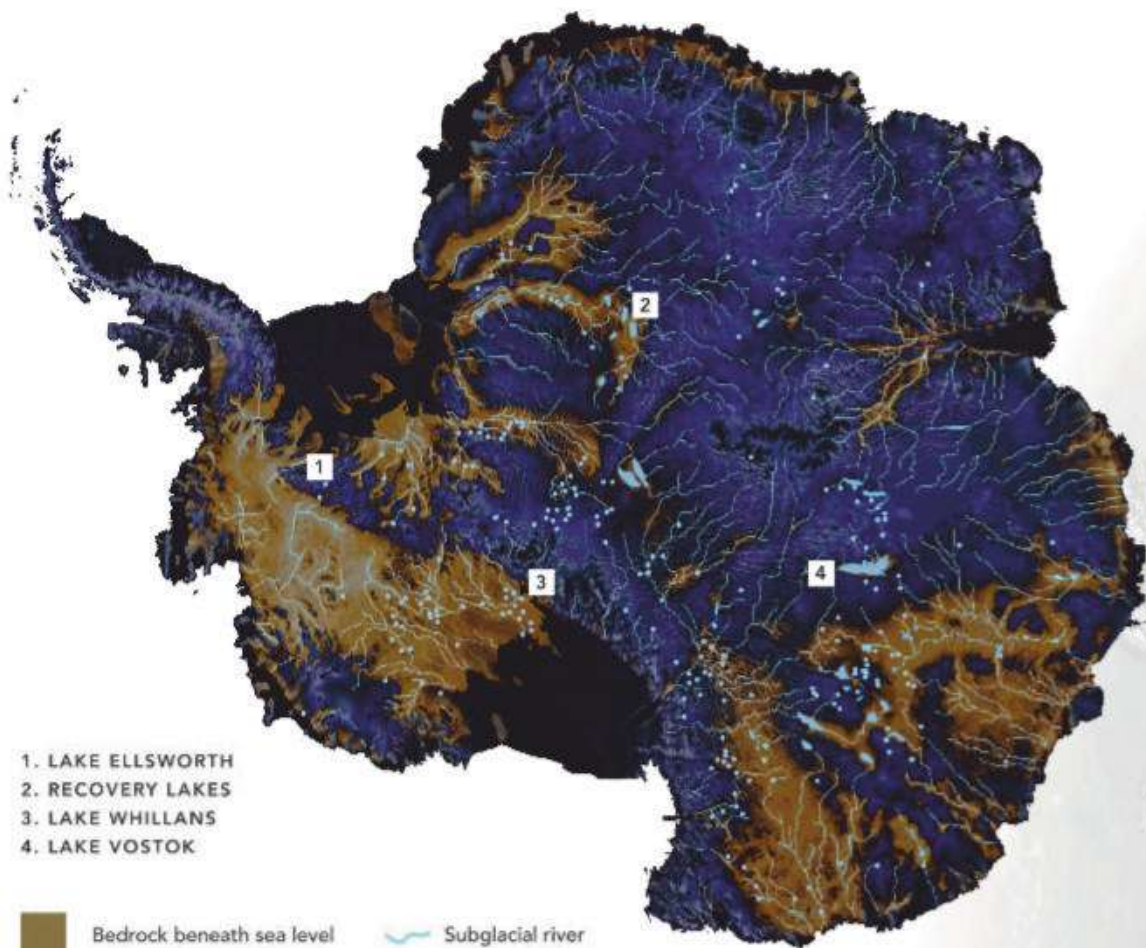
PhD: Semi-supervised learning (artificial intelligence) for volumetric segmentation

PhD: Visualization of self organization of dislocations using an x-ray microscope

Post doc: Dark field x-ray microscopy

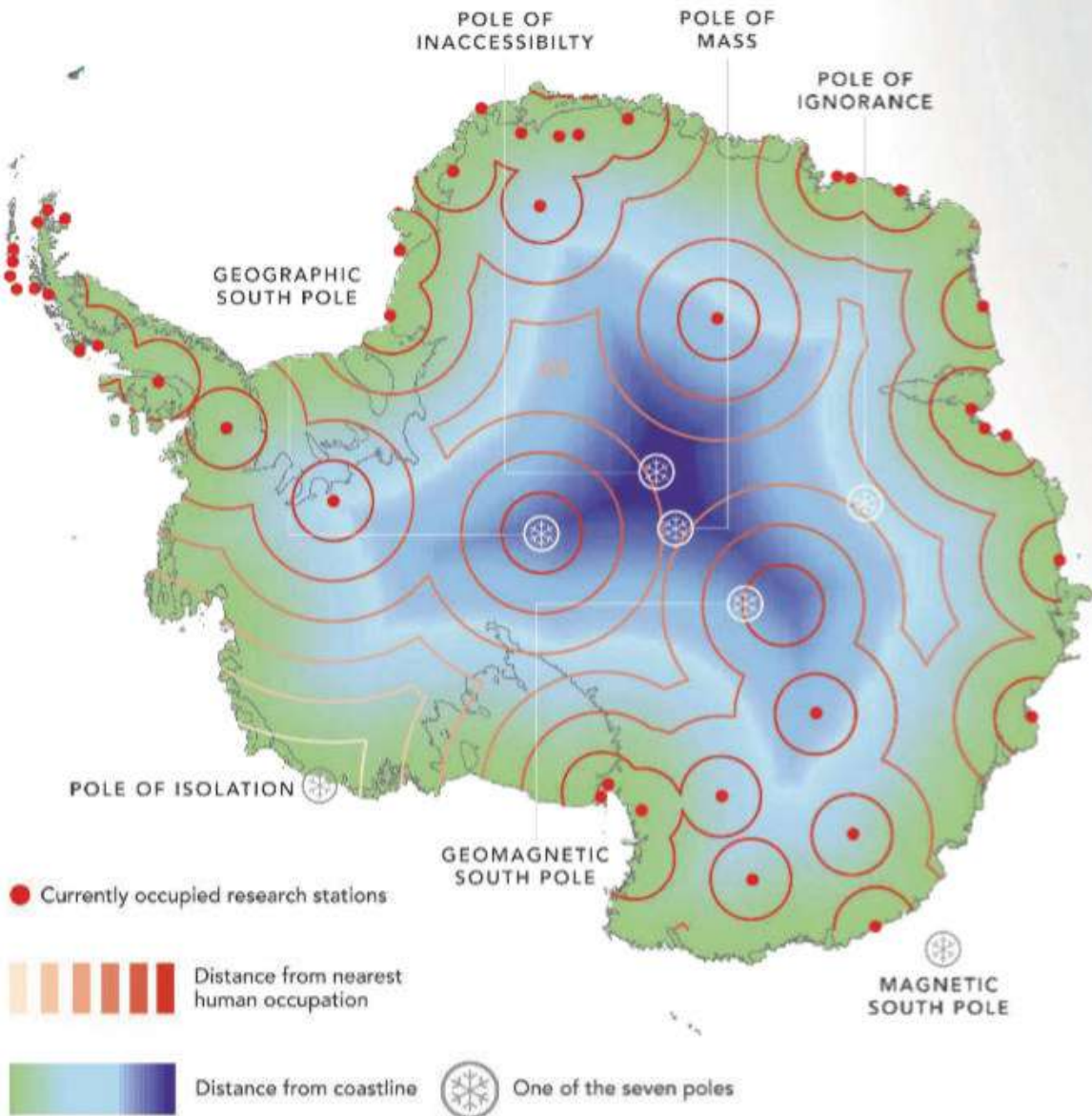
PhD: Phase contrast imaging with neutrons

PhD: Diffraction imaging with neutrons



- 1. LAKE ELLSWORTH
- 2. RECOVERY LAKES
- 3. LAKE WHILLANS
- 4. LAKE VOSTOK

- Bedrock beneath sea level
- Subglacial river
- Bedrock above sea level
- Large subglacial lake
- Smaller subglacial lake



Currently occupied research stations

Distance from nearest human occupation

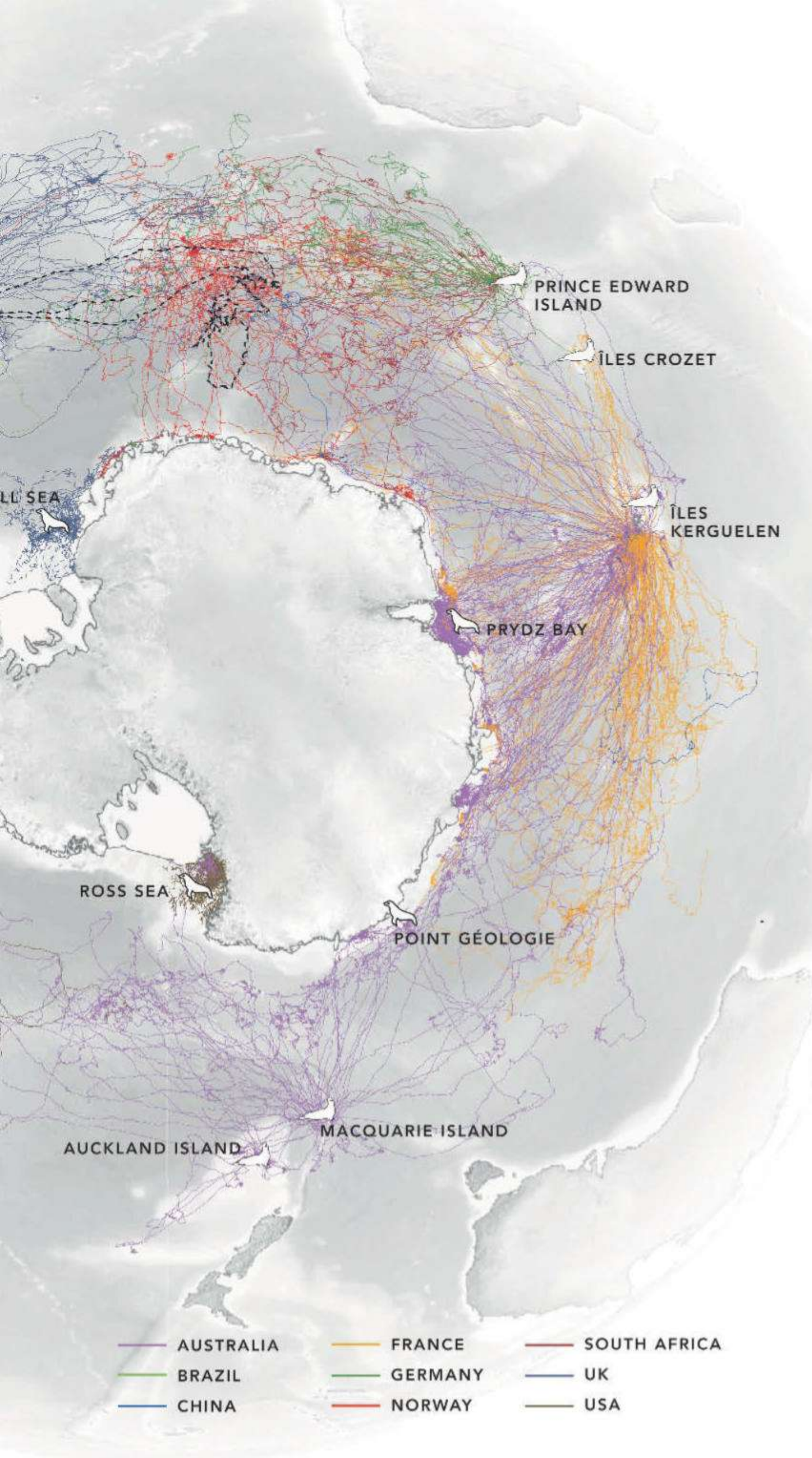
Distance from coastline

One of the seven poles

MAGNETIC SOUTH POLE

- Elephant seal
- Weddell seal
- Longest single track





Antarctic lines



Cartographer **Peter Fretwell**

THE otherworldly continent of Antarctica seems all the more fantastical when seen from a new perspective, as shown in these maps laying out its different features in detail.

The maps were devised and created by Peter Fretwell, a cartographer and scientist with the British Antarctic Survey. They are part of his new book, *Antarctic Atlas: New maps and graphics that tell the story of a continent*, a collection of carefully constructed maps setting out Antarctica's geology, people and nature, as well as its history and future.

Fretwell used powerful computers and satellite observations to put together maps of the continent's diverse features, such as its ice flow and patterns, islands and atmosphere. It is a feat that now takes hours per map compared with the month-long timescale before technological advances. These days, cartographers can obtain data almost instantly.

The map at the top left reveals the intricate network of lakes and streams hidden beneath Antarctica's vast expanses of ice, some of which run for thousands of kilometres. The one to its right documents the sprawling paths of individual seals, such as elephant seals, that journey through the Southern Ocean looking for food. The lines are coloured according to the nationality of the science team that placed the tag on the seal. The third map pinpoints the poles dotted across the continent. Though it is famous as the home of the South Pole, there are in fact a total of seven poles in Antarctica – either geographical or magnetic. ■

Gege Li

It's hard to know what lies ahead

Whatever happens in 2021, get the clearest
possible view with *New Scientist*



**New
Scientist**
Subscriptions

Week in, week out, our reporters are talking to the experts and sifting through the latest results from the cutting edge of science and technology – so that, whatever happens in 2021, you are ahead of the curve.

Find out for yourself with our January sale offer:
12 weeks for half price

***New Scientist* subscribers
get so much more than the magazine:**

51
print editions
through your
letter box

365
days of
unlimited access to
newscientist.com

400+
issues in the *New
Scientist* app (including
the current issue)

200+
video science
talks to immerse
yourself in

200+
interactive
puzzles and crosswords
(added weekly)

4
exclusive
subscriber-only
online events

All this for just £2.71 a week*

Visit newscientist.com/jansale

Call: +44 (0) 330 333 9470, quoting 16092



**JANUARY SALE
HALF PRICE
FOR 12 WEEKS**

***New Scientist.*
The world, better understood**

Weekly price based on a 12 week bundle subscription (print + app + web). After your first 12 weeks your subscription will continue at the full rate. You can cancel anytime before the first full payment and no further charges will be applied. Offer closes 15th March 2021.

Measuring up the universe

In the past century, cosmologists have created an epic story of an unimaginably vast cosmos that began billions of years ago in a big bang.

But can we be sure they have got it right?

Stuart Clark audits our cosmological knowledge, providing an essential overview of what we think we know about the universe's vital statistics – and where there is work still to do

HOW OLD IS THE UNIVERSE?

A CENTURY ago, if you asked a cosmologist the universe's age, the answer may well have been "infinite". It was a neat way to sidestep the question of how it formed, and the idea had been enshrined in 1917 when Albert Einstein presented his model of a static universe through his general theory of relativity.

General relativity describes gravity, the force that sculpts the universe, as the result of mass warping its fabric, space-time. In the mid-1920s, astrophysicist George Lemaître showed that according to the theory, the universe wasn't static but expanding – and would thus have been smaller in the past.

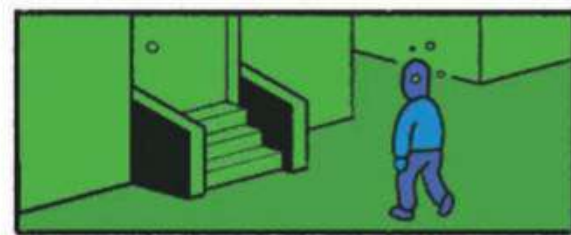
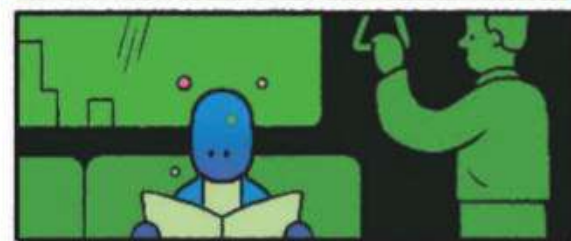
Lemaître's idea that everything there is was once contained in a single "primordial atom" was transformed in the 1960s, when astronomers discovered the most ancient light in the universe, the cosmic microwave background. This indicated that everything had begun in a hot, dense state: the big bang.

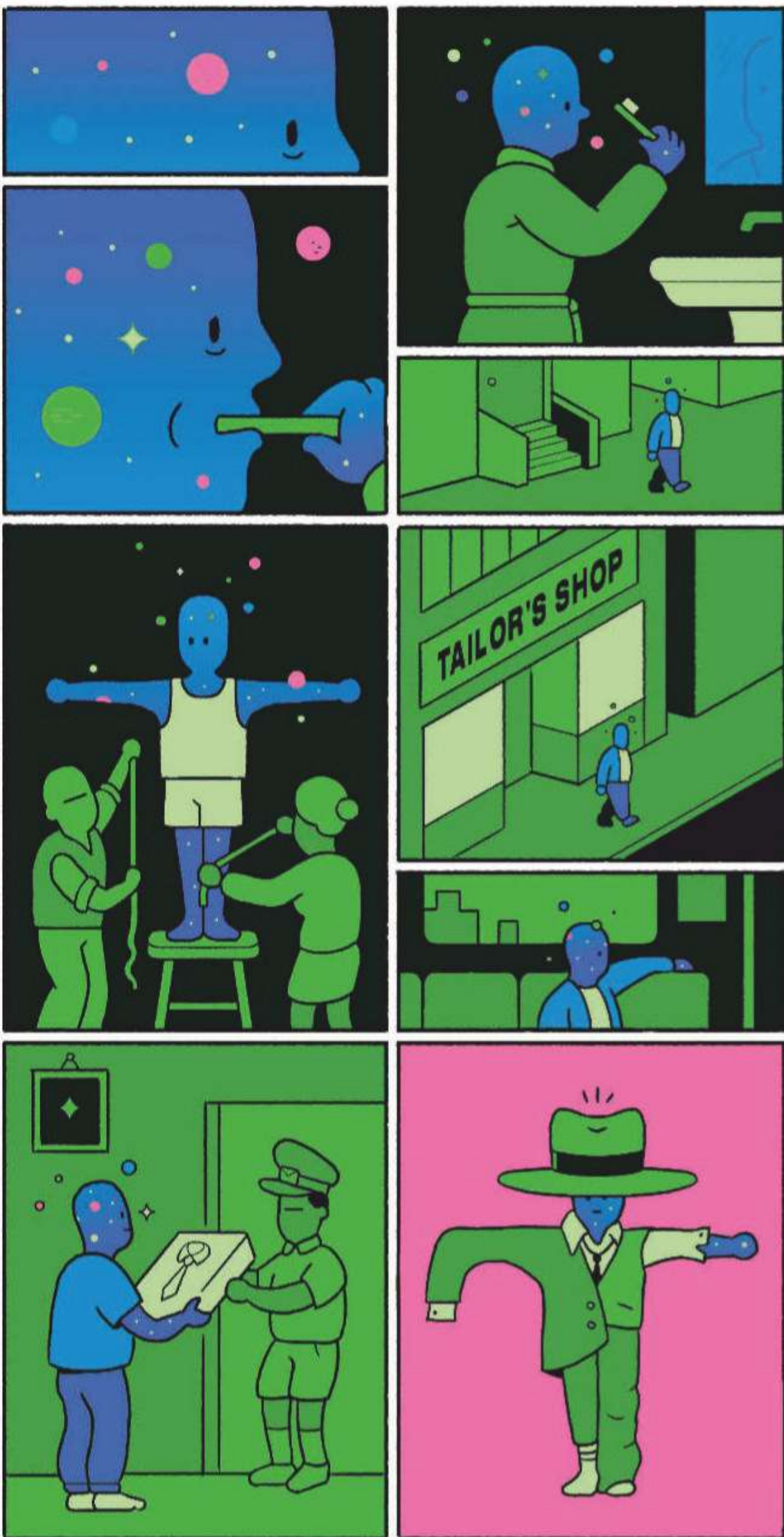
These days, most cosmologists are confident that happened about 13.85 billion years ago. The figure is based on estimates

of the universe's expansion. There is some uncertainty there, because methods for estimating that rate spit out different values (see "How fast is the universe expanding", page 35). The possible range of ages is between 12 billion and 14.5 billion years.

We can cross-check that against the oldest star we know. It's clear that HD 140283, aka the Methuselah star, is ancient because it is made almost entirely of hydrogen and helium, the predominant elements in existence in the aftermath of the big bang. Now, astronomers reckon it is 14.46 billion years old, give or take 0.8 billion years. That could make it slightly older than the universe.

But the fact that the age of the oldest star we can find is so close to our estimates of the universe's age suggests that the standard model of cosmology – our general relativistic model of how the universe evolved, which supplies these estimates – is secure. How long the cosmos has existed isn't really in doubt. For many other properties of the universe, we can't be so sure.





HOW BIG IS THE UNIVERSE?

Stare out at the night sky for any length of time and you'll ponder how far it all extends. For most of human history, the universe was commonly thought to be separate from Earth and the stars surrounding it – a sort of no-man's land between us and heaven. Yet since the scientific revolution in the 17th century, astronomers have come up with various ways to measure distances to celestial objects.

These methods are collectively known as the cosmic distance ladder (see "Ladder to the stars", page 34). "It's basically a bootstrap thing," says James Schombert at the University of Oregon. Each part of the ladder builds on the one below until, eventually, you reach distant celestial objects bright enough to be seen across the grandest cosmic scales: galaxies and exploding stars called supernovae.

This means we can measure the universe in its entirety, or at least we can try. The most distant galaxy known is GN-z11. Light from it has taken 13.4 billion years to reach us – most of the age of the universe. In that time, ➤

space-time has expanded. Working from the rate of expansion given by the standard model, this galaxy is probably now about 32 billion light years away from us. Extrapolating to the entire observable universe, astronomers estimate it has a diameter of 93 billion light years, or very roughly 10^{26} metres (100 million billion billion kilometres).

But that is just the distance between the furthest things we can see. “You don’t walk 10^{26} metres and then hit a brick wall,” says Tony Padilla at the University of Nottingham, UK. “The universe goes beyond that.”

We can’t see past this cosmological horizon. Instead, we make inferences based on what the standard model of cosmology tells us. Most cosmologists believe that, immediately after the big bang, the universe underwent a moment of exponential expansion known as cosmic inflation. It is the best way to square our observations of a smooth, uniform universe at the

grandest scales with the big bang, because quantum theory tells us that tiny energy fluctuations in random places would have created an uneven distribution of matter. Without inflation, that randomness could not have evened out during the time since the big bang.

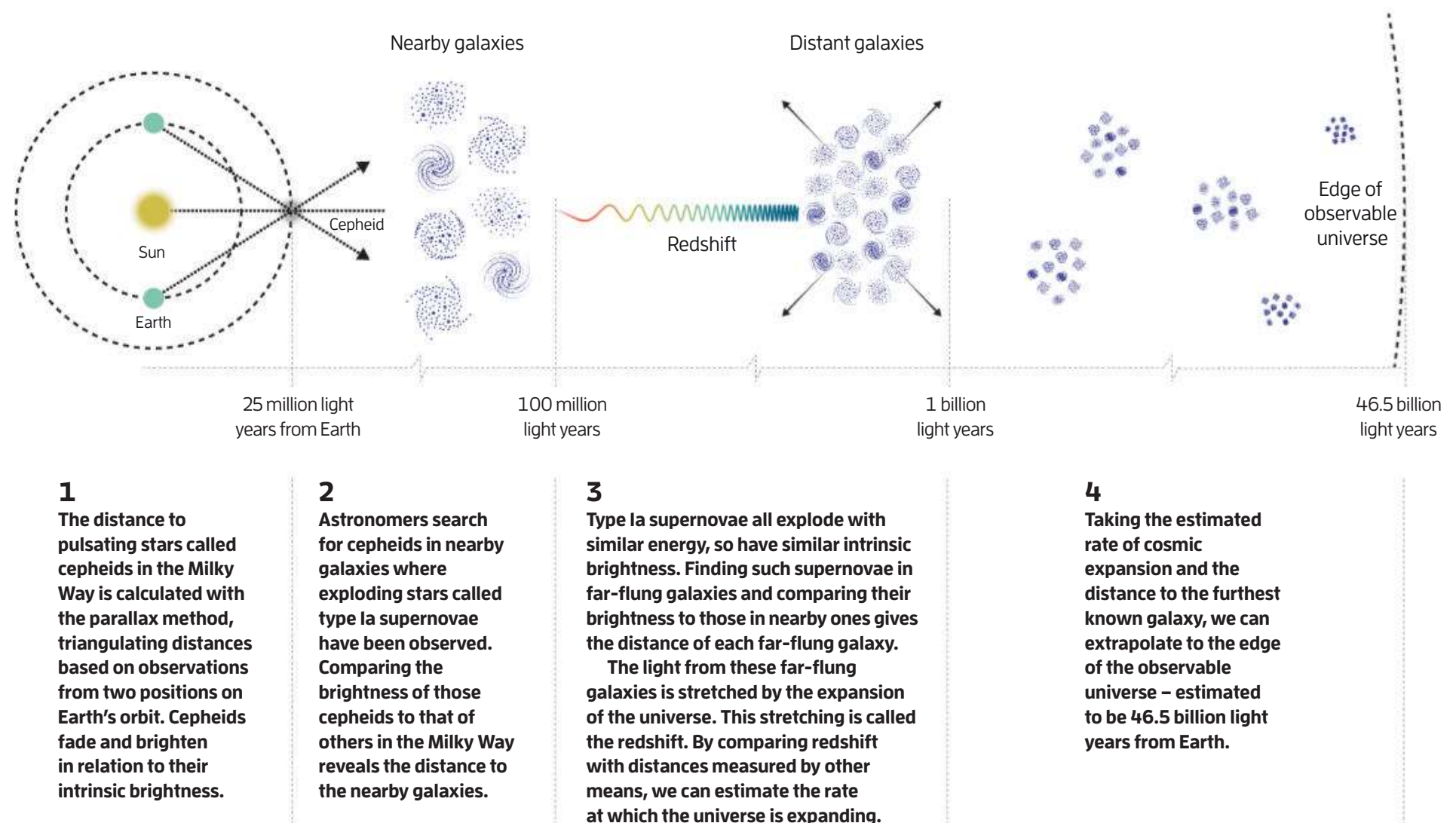
Inflation also happens to suggest a universe much larger than that we can see. Whereas the “inflaton” field thought to have powered it stopped at some point in our region of the wider universe, it would continue to spark fresh bouts of inflation elsewhere. “You get really big universes in these [eternal inflation] scenarios, and I mean just off-the-scale huge,” says Padilla.

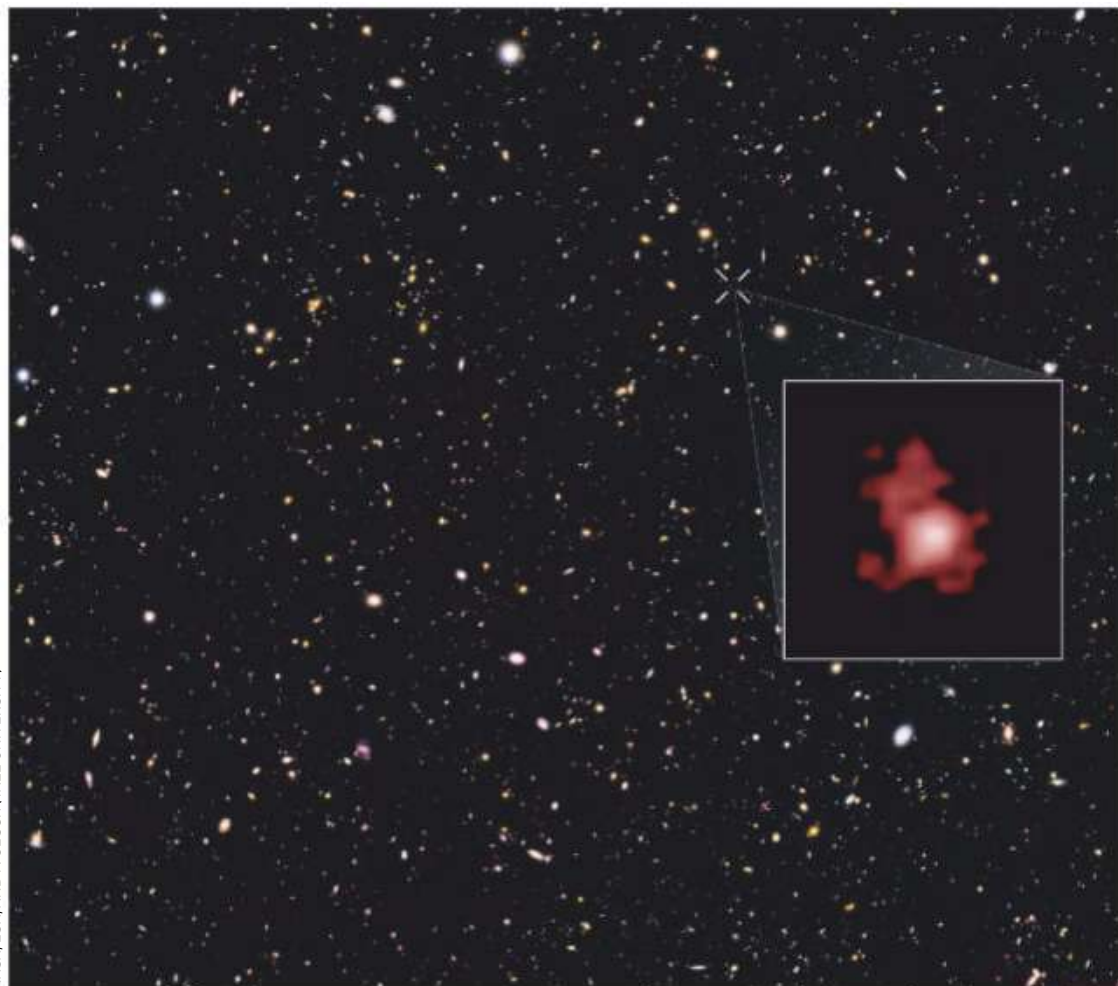
Whether or not they are part of our universe, or separate, is a matter of perspective (see “How many universes are there?”, page 37). Clearly though, to understand the size of the universe beyond the cosmological horizon, we need a better picture of the universe’s first moments.

“Cosmic inflation suggests a universe much larger than the one we can see”

Ladder to the stars

Astronomers estimate the distances from us to celestial objects with a succession of methods called the cosmic distance ladder, so named because each technique relies on the previous one





The most distant known galaxy is GN-z11, roughly 32 billion light years from Earth

HOW FAST IS THE UNIVERSE EXPANDING?

Space-time is getting bigger all the time, like dough rising in the oven. The observational proof of this came in 1929, when astronomer Edwin Hubble demonstrated that distant galaxies are speeding away from our own. We have even been able to clock the expansion rate, measured as the speed at which every million parsecs of space expands per second, by measuring the distance to numerous galaxies and comparing those distances with their redshift – the extent to which light emitted by each galaxy is stretched as a result of the universe’s expansion.

In the early 2000s, the Hubble Space Telescope showed that the current expansion rate was close to 75 kilometres per second per megaparsec. Cosmologists thought they had this one nailed. All that remained was to measure how much this rate was slowing as the gravitational pull of all the universe’s matter and energy fought to drag things together. When the answer came, it broke everything.

In the late 1990s, we discovered that the expansion wasn’t slowing down at all. On the contrary, it was speeding up – and nothing in

known physics could explain it. The only thing that might fit the bill was a fudge factor that Einstein had included in his equations of general relativity when he thought the universe was static. Dialled up, this “cosmological constant” could reverse the deceleration from gravity and power an accelerating expansion. This was the birth of dark energy, a mysterious addition to the standard model of cosmology that continues to evade characterisation.

The conundrum only got more intractable in 2013, when the Planck satellite from the European Space Agency (ESA) returned the most precise map yet of the cosmic microwave background. Feeding that data into the standard model and running the clock forwards, researchers calculated that the universe should be expanding at 68 kilometres per second per megaparsec – slower than the rate we get from supernovae.

To bring the two values into alignment, physicists refined their calculations and better quantified the sources of possible error, only to see the discrepancy grow. The tension means that the standard model is incapable of describing the universe as we observe it. Now some cosmologists are wondering if general relativity, the model’s foundation stone, needs resetting.

There is certainly wiggle room. Tessa Baker, a cosmologist at Queen Mary University of London, says that although tests of gravity across the solar system, and in other specific situations, are extraordinarily precise, there is still plenty of scope for gravity to work differently from how Einstein predicted at the largest cosmological scales. “The experimental bounds we have on gravity operating over distance scales of megaparsecs or so are really weak,” she says. The strength of gravity could plausibly be 10 to 20 per cent stronger on those scales, she adds.

Naturally, theorists are having a field day. But Chris Van Den Broeck, a physicist at the National Institute for Subatomic Physics in Amsterdam, the Netherlands, isn’t ready to sound the standard model’s death knell yet. “The tension is there, but I’m not yet convinced that we should panic,” he says. ➤

HOW HEAVY IS THE UNIVERSE?

Calculating how much stuff there is in the universe has long preoccupied cosmologists, largely because it seems that so much of it is invisible.

Take dark matter, so named because it doesn't interact with light. This mysterious source of mass was invoked to explain how galaxies and clusters of galaxies hold together when we realised that the gravitational pull of ordinary visible matter alone isn't enough to do the job. It has since become a vital component of the standard model, its hidden gravitational hand sculpting the structure of the cosmos.

We still haven't detected dark matter. Yet by looking at the pattern of temperature fluctuation in the cosmic microwave background, indicative of the interplay of matter and energy in the early universe, physicists are able to estimate its abundance compared with ordinary matter. The upshot is that dark matter outweighs normal matter by more than 5 to 1. The cosmos is roughly 5 per cent ordinary matter, 27 per cent dark matter and 68 per cent dark energy – that other mysterious form of mass/energy. This much is gospel – at least for now.

Recently, however, a puzzle has emerged from measurements of the extent to which galaxies clump together on a scale of 8 kiloparsecs. The value of this

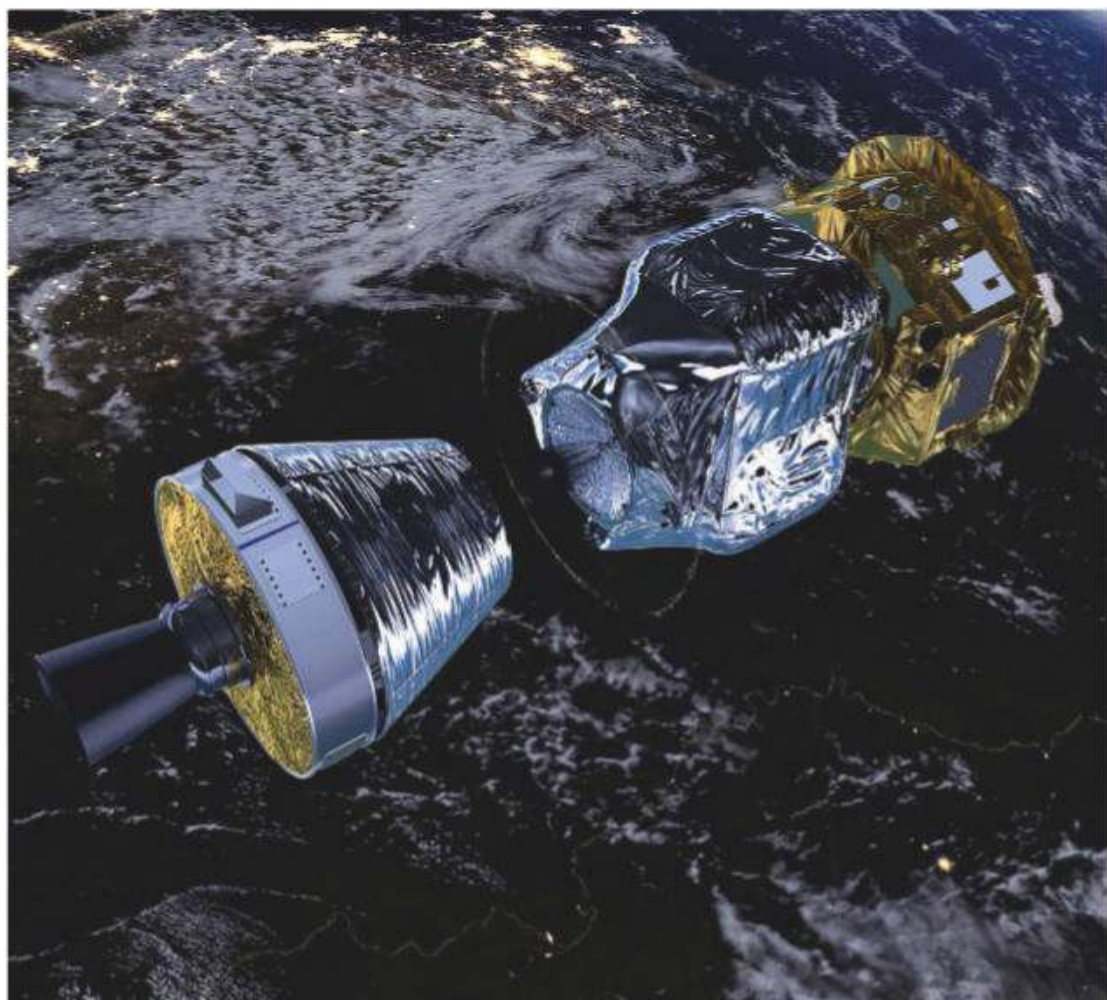
quantity, known as σ_8 , depends on how much mass there is in the universe, because it is the gravity resulting from this mass that pulls the clusters together. We can measure it based on observations or we can predict it based on the standard model. Again, precise measurements produce a troubling discrepancy.

Working from established ratios of the different kinds of matter and the behaviour of gravity as described by general relativity, the standard model predicts that σ_8 should be 0.81. But when Hendrik Hildebrandt at Ruhr-University Bochum, Germany, and his colleagues measured this value in 2017, they got a different answer. He and his team used a technique called weak gravitational lensing, which measures the extent to which light from distant galaxies is distorted by massive objects between us and them. Their value for σ_8 came out at 0.74, suggesting that there is less matter in the universe than we predict when using the standard model.

Future observatories such as the ground-based Vera Rubin Observatory and the ESA's space-borne Euclid mission are scheduled to devote time to refining this measurement. If the discrepancy remains, it will need explaining. If it can't be explained, then there's another reason to think our standard cosmology needs an overhaul.

The LISA Pathfinder satellite, a prototype for a probe that could reveal the true shape of the universe

“The latest measurements suggest there is less matter in the universe than expected”



ESA/ATG MEDIALAB

WHAT SHAPE IS THE UNIVERSE?

When cosmologists talk about the geometry of the universe, they are referring to the overall shape of space-time. In our expanding universe, there are basically two possibilities. If the gravity produced by all matter is stronger than the expansion, it will ultimately pull everything back together. In that case, we are living in a “closed” or spherical universe. If whatever is driving the expansion overpowers gravity, however, then we have a perpetually expanding or “open” universe that looks like a saddle (see “Cosmic contours”, below).

Intriguingly, however, the universe seems to be precariously balanced between these two options. The theory of cosmic inflation helps to explain this fluke by ironing out our perception of any overall curvature, and the idea that we reside in a flat universe is now hardwired into cosmology’s standard model. Even so, there are suspicions.

Alessandro Melchiorri at Sapienza University in Rome, Italy, is part of a team that analysed the latest data from the Planck mission, which measured temperature fluctuations across the cosmic microwave background to the most precise level ever achieved. One thing the researchers analysed was the extent to which light from the

cosmic microwave background is distorted by the process of weak gravitational lensing as it travels towards us. They found more lensing than the standard model of cosmology predicts – unless you remove the assumption of a flat universe. “If you perform a model fit, leaving the curvature to vary, you see that the best solution is a closed universe with more dark matter,” says Melchiorri.

But as Melchiorri and his colleagues demonstrated in a follow-up study earlier this year, a closed universe exacerbates the discrepancies cosmologists are seeing elsewhere in the standard model, not least the fact that the universe seems to be expanding faster than predictions suggest it should. Explaining that gets even harder if the universe is spherical rather than flat.

Pretty much every other measurement we have suggests that the universe is flat. It is possible that this latest observation is a statistical fluke that disappears with new cosmological surveys from the Vera Rubin telescope or the Euclid satellite, for instance.

If not, however, then the best way forward is to extract better data about the true nature of the big bang and cosmic inflation. This is where gravitational waves come in. These ripples in space-time, best known as the

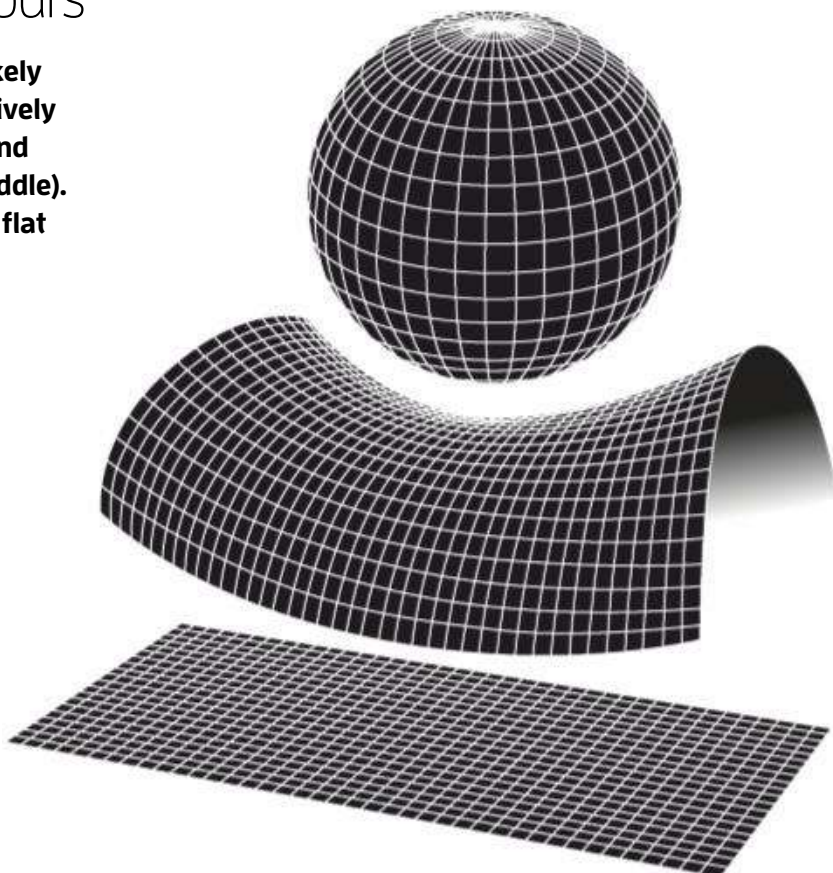
result of collisions between distant black holes, can also open a window onto the early universe if we can detect any that have made their way to us from the furthest reaches of the cosmos. “There are a bunch of [cosmological] mechanisms that could conceivably have caused a flash of gravitational radiation a fraction of a second after the big bang,” says Van Den Broeck – mechanisms like inflation.

Primordial gravitational waves would be visible today as a background of ripples, coming from all directions. They are distinct in the sense that they would have much longer wavelengths than the ones we have detected from black hole collisions, thanks to the expansion of the universe. Our best ground-based gravitational wave detectors operate at too high a frequency to see them. But the ESA’s planned space-based detector, the Laser Interferometer Space Antenna (LISA), could.

“If we could also see primordial gravitational waves that would be really thrilling,” says Padilla. “Then we would really start to learn a lot about the universe.” Perhaps most importantly, we could learn whether inflation truly happened – and whether the universe is flat after all.

Curious contours

The cosmos is most likely to be closed and positively curved (top) or open and negatively curved (middle). And yet it seems to be flat (bottom) – or does it?



HOW MANY UNIVERSES ARE THERE?

As mentioned earlier, when cosmologists came up with cosmic inflation, the idea that the early universe ballooned exponentially in a moment, they quickly realised they may have got more than they bargained for. “Inflation can happen anywhere in space and time,” says Padilla, “It happened in our patch of the universe a long time ago, and it made our corner of the universe very large, but there could be different parts of the universe where it’s still going on.”

This scenario, known as eternal inflation, produces a pantheon of different “bubble” universes, all crowded together, with more budding off all the time. Welcome to the inflationary multiverse. There is no way to observe or measure it because all the



The fate of the universe depends on the true nature of dark energy

bubble universes it contains lie outside the limits of our observable universe. Instead, many cosmologists are convinced it exists because it is a logical consequence of two theories, inflation and quantum mechanics, that have been demonstrated to be valid to varying degrees.

Not being able to see them hasn't prevented people from speculating about how many universes there might be, and what they might contain.

With the standard-issue inflationary multiverse, the number of universes is endless. What we find in each one could be something wildly different from the universe we know. This idea of a cosmic pick-and-mix grew out of attempts to explain gravity in the same way as the other three forces of nature, as a quantum force. These string theories replace familiar point-like particles with tiny vibrating strings that exist in multiple dimensions – normally 10 or 11 of them, depending on your preferred version – and predict a vast landscape of at least 10^{500} different possibilities for how physics might look in the myriad bubbles of the inflationary multiverse. Each would have different physical laws and different values for the constants of nature.

Or maybe there is just one other universe, and we have already seen tangible evidence of its existence. In 2016, the Antarctic Impulsive Transient Antenna (ANITA) detected a high-energy particle that instead of heading in from space, appeared to be blasting out of Earth. Two years later, it made a second such discovery. One explanation is that the particle might have come from a parallel universe created concurrently with our own, but travelling backwards in time.

“You’d barely notice the end of the universe. Blink and it will all be over”



WHEN WILL THE UNIVERSE END?

Before the discovery of dark energy, the mysterious force thought to be pushing space-time apart, the future of the universe depended on geometry. Either the cosmos was closed and would collapse in on itself in a “big crunch” or it was open and would expand forever. Now, however, cosmology’s standard model assumes that we live in a flat universe that, thanks to dark energy, will expand eternally.

If dark energy is nothing more exotic than a cosmological constant, meaning it doesn’t fluctuate over time, then the expansion of the universe will itself eventually become a constant, carrying the clusters of galaxies ever further away from one another. “We’ll be left pretty much alone in the universe,” says Baker. In this scenario, sometimes called the heat death of the universe, or the big freeze, all the stars eventually die, black holes grow larger and the remaining matter in the universe tends to equalise in temperature. With no difference in temperature, energy cannot flow and gradually the universe enters a kind of cosmic senescence, where nothing much happens at all.

An alternative is the big rip. Here, the dark energy keeps getting stronger and the expansion of the universe keeps accelerating. “This is more exciting,” says Baker, “Even gravitationally bound objects like a galaxy can eventually get pulled apart”, as dark energy overpowers the gravity holding the celestial objects together.

Which of these scenarios is correct will only be revealed once we know the nature of dark energy. But before you get too comfortable thinking that this is all so far in the future that you don’t need to worry about it, there is one way that the universe could end tomorrow. It rests on the idea, from string theory, that there is a vast landscape of universes with different physical laws. If so, our universe could perform a quantum trick called tunnelling, in which it would suddenly transform itself into a universe with different properties. The constants of nature and perhaps even the laws of physics would be nothing like the ones we know.

That wouldn’t be ideal, to say the least, because the structure of atoms relies on the delicate balance between the forces of nature. Upset it, and the atoms that comprise everything could disintegrate in a flash. “If we undergo one of these phase transitions at teatime tomorrow, you’d barely notice it,” says Baker. “Blink and it’ll all be over.”

The ultimate question for cosmologists, then, might be whether or not they can figure out if their beloved standard model is correct before quantum oblivion beckons. Watch this space-time continuum. ■



Stuart Clark is a consultant for *New Scientist*. His latest book is *Beneath the Night* (Faber)

SHUTTERSTOCK/BIGPIXEL PHOTO; STEPHANIE ROSSOW/CDC



The other superbugs

Killer viruses and antibiotic-resistant bacteria aren't the only infectious threats we face – deadly fungi are coming for us too, finds **Nic Fleming**

IN THE month the first lockdown began in England, the number of people seeking emergency hospital treatment fell by around half. It wasn't that fewer people needed urgent care, but that many feared catching coronavirus, according to doctors. Those concerns are understandable. While control measures have improved since, in May it was estimated that 5 to 20 per cent of people in English hospitals with covid-19 got it while being treated for something else.

The problem of potentially deadly hospital-

acquired infections isn't restricted to the pandemic. Every year, hundreds of millions of people admitted to hospital globally end up with infections that can be more dangerous than their initial condition. The best known causes include methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* (*C. diff*), often called superbugs for their ability to shrug off antibiotic treatments. A growing list of conditions, such as pneumonia, tuberculosis sepsis and gonorrhoea, are becoming harder to treat because of antibiotic resistance.

As the current pandemic makes painfully clear, bacteria aren't the only microbes able to adapt at our expense. In the past few years, a new threat has been setting off alarm bells: treatment-resistant fungal infections. There have been outbreaks at hospitals around the world. Worryingly, 90 per cent of infections caused by the main culprit, *Candida auris*, are now resistant to one of our mainstay antifungal drugs.

This resistance is developing at an "unprecedented" pace, according to a recent assessment, which warns that the problem isn't just spreading in our hospitals, but also in fields, gardens and the very air we breathe. So how big is the problem? And what can be done? ➤



***Candida auris* was unknown before 2009, but has rapidly spread worldwide**

As with bacteria, thousands of different species of fungi live alongside or within us. Most cause no harm or even serve us well, helping us grow crops, brew beer or make the perfect sourdough. But since at least 500 BC, we have known that fungi can also give us dangerous and even deadly infections.

It was only in 1950 that the first effective antifungal treatment was discovered, and the efficacy of early antifungals was hit and miss. Then, in the late 1960s, came a new class of drugs called azoles, which work by disrupting fungal cell membranes. Although marking a huge step forward, these often had harsh side effects. When more targeted versions of these drugs, known as triazoles, were introduced starting in the late 1980s, we finally had powerful, effective antifungal medicines with far fewer side effects. Today, we have three main kinds of medicines that work against fungal infections: triazoles, amphotericin B and echinocandins.

Most people fend off potential fungal infections without treatment. For instance,

Aspergillus fumigatus is so abundant in decaying plants and other organic matter that humans inhale hundreds of its spores daily, and they are usually mopped up by immune cells in the lungs. In people with compromised immunity, though, perhaps due to HIV, chronic lung disease, cancer treatment or post-transplant medicines, *A. fumigatus* can reproduce and get into the bloodstream. Every year, about 250,000 people worldwide get this condition, known as invasive aspergillosis. That is why having effective medicines is so critical. Before triazoles were developed in the 1990s, the death rate for this condition was around 45 per cent. Today it is 30 per cent.

Hard to kill

But it is a relative newcomer that is most quickly outpacing our best medicines. A member of the same genus of fungi that causes thrush, *C. auris* was first identified in a Japanese woman's ear in 2009. Within a few

years, infections by treatment-resistant *C. auris* were reported in Asia, Africa and the Middle East. Fungi are rarely capable of efficient transmission between people, yet *C. auris* has spread rapidly in hospitals on six continents. Most strains are resistant to one or two of the three main classes of antifungal drugs. Some are resistant to all three.

The first *C. auris* outbreak in Europe began in 2015 at the Royal Brompton Hospital in London, where early efforts to kill the fungus and stop it spreading among patients failed. "It's almost the perfect pathogen," says Johanna Rhodes, a genomic epidemiologist at Imperial College London, who was called in to help deal with the outbreak. "One of the things that makes *Candida auris* so scary is the fact it can linger on inanimate surfaces for long periods and withstand whatever you throw at it." The fungi could remain viable on surfaces for 28 days, despite several rounds of standard hospital disinfectant procedures, Rhodes found. One US hospital had to rip out ceilings and floor tiles to get rid of it.

In all, some 72 patients tested positive for treatment-resistant *C. auris* during the Royal Brompton outbreak. By February 2019, there had been more than 260 cases in the UK. Since 2009, there have been cases in more than 30 countries, including 1000 in the US, and major outbreaks in Spain, Venezuela, Colombia, India and Pakistan. When *C. auris* infections get into the bloodstream, they prove fatal within weeks in more than one in three cases, according to the US Centers for Disease Control and Prevention (CDC), although it can be hard to determine whether people die with or because of the infection because it often affects those with other severe health problems.

That is worrying when we are running out of ways to fight back against resistant fungi. "We're now seeing strains that are resistant to all classes of antifungals," says Mahmoud Ghannoum, a fungal diseases specialist at Case Western Reserve University in Ohio. "We've always had multidrug-resistant bacteria, but we didn't have the situation with fungus until now."

Because many healthcare systems don't have effective monitoring in place, let alone access to the most accurate genetic tests used

to identify resistant strains, figures on the scale and spread of the problem are likely to significantly underestimate the threat. Many cases go undiagnosed or are misdiagnosed as other conditions. What is clear, however, is that the incidence of treatment-resistant infections is on the rise.

Studies in Dutch hospitals have shown that azole resistance in *A. fumigatus* samples taken from patients nearly doubled from 7.6 per cent in 2013 to 14.7 per cent in 2018. In 2019, nearly 7 per cent of *A. fumigatus* strains found in soil samples in southern England tested positive for azole resistance. Resistant strains have also been reported elsewhere in Europe, the Middle East, South-East Asia, the US, Colombia, Australia and Tanzania.

Between 2015 and 2018, resistance in

“*Candida auris* is scary – it can live on surfaces for long periods and withstand whatever you throw at it”

England to three different antifungal drugs rose significantly in samples of *Candida glabrata*, which can cause bloodstream infections. Other *Aspergillus* and *Candida* species also exhibit resistance to antifungals including triazoles, as do other fungal pathogens including *Scedosporium* and *Fusarium* species, both commonly found in soils.

For the most part, all these strains of fungi are resistant to azoles and triazoles. But it isn't as simple as opting to use the other two main kinds of antifungals instead. In general, amphotericin B and the echinocandins are less effective, have more side effects, can't be tolerated by some people and often require daily intravenous therapy in hospital. Paul Verweij at Radboud University Medical Center in the Netherlands found that 62 per cent of patients with invasive aspergillosis who were treated with other drugs because they didn't respond to triazoles died within 90 days, compared with 37 per cent for those without a triazole-resistant infection.

What is driving this shift – and why does it seem to be happening so fast? For some fungi, the first clues may have been apparent nearly 20 years ago. When Verweij and his team were testing patient samples of *A. fumigatus* to establish the optimum doses of triazoles, they noticed something perplexing. It isn't unusual for fungi to develop resistance to drugs following a period of treatment. “However, we had samples from patients who hadn't been treated with azoles that were still resistant,” says Verweij. On further investigation, he and his colleagues found that no pre-1999 samples exhibited resistance and of the 32 later samples that did, 30 had the same genetic mutation. “You would expect more genetic diversity if resistance had evolved in patients, suggesting the driver of resistance was in the wider environment,” he says.

More recent work has shown that two genetic mutations are dominant in antifungal-resistant *A. fumigatus* found in the environment, and these account for 80 to 90 per cent of resistant strains of this species collected from patients.

This may be an unfortunate side effect of efforts to adopt a greener agriculture ➤

***Aspergillus fumigatus* grows in household dust**



system and reduce waste. In 2016, the Dutch government adopted a circular economy strategy in which farmers were encouraged to turn green waste such as stalks and dead leaves into compost using long piles called windrows. These contain both huge quantities of *A. fumigatus* spores and residues of azole fungicides used to protect crops. Tulip bulb farms, agricultural green waste and wood chippings provide the ideal conditions for *A. fumigatus* to build up azole resistance. “Thanks to work in the Netherlands, we now know azole resistance is associated with certain intensely farmed environments,” says Matthew Fisher at Imperial College London. Other countries, including China and Iran, have also documented the spread of azole-resistant *A. fumigatus*. Now researchers are trying to work out whether resistance is developing independently in different locations or being carried by spores on the wind.

The cause of rising resistance isn’t quite as clear with *C. auris*. It was initially thought the rapid spread to multiple countries meant it had hitched a lift with travellers. Then, research showed there were four genetically distinct forms, from Japan, India and Pakistan, South Africa and Venezuela. “It’s a real conundrum,” says Fisher. “It implies that *C. auris* was present in these places, without causing disease and at low prevalence, and then something changed in the environment to allow it to take off within a narrow window of time.”

After finding that *C. auris* can grow at higher temperatures than related species, Arturo Casadevall at the Johns Hopkins Bloomberg School of Public Health in Maryland and his colleagues speculated that it has adapted to thrive in warm environments, including the human body, due to climate change.

Others point to the wide use of azole-based fungicides, which make up around a quarter of those used in agriculture in the European Union, for example. Recent work suggests that different *C. auris* strains share a natural resistance to azole-based compounds, meaning this adaptation probably isn’t recent. It is more likely that this natural defence allowed *C. auris* to move into niches

“It is harder to make new antifungals than antibiotics because we are more closely related to fungi”

Use of antifungals in agriculture may be driving resistance

vacated by more susceptible fungal rivals, says Tom Chiller at the US Centers for Disease Control.

Most in the field are convinced that *C. auris* emerged because humans suppressed other fungal pathogens, but many researchers believe this has largely taken place in hospitals through the widespread use of triazoles. “The most compelling hypothesis is that overuse of azoles in the clinic has created an open ecological niche for *C. auris* and led to a restructuring of the fungal populations that parasitise humans,” says Fisher.

There are now several large-scale efforts to better understand the causes of antifungal resistance and how to combat it. In March, UK research charity the Wellcome Trust awarded £2.2 million to a group including Fisher and Verweij to sequence samples from thousands of patients infected with *A. fumigatus*. Another group in the Netherlands is seeking to better understand how large-scale composting drives resistance, and to find solutions. “Keeping green waste out of the rain might make it too dry for



DAVID ROBERTSON/LAMY

Aspergillus to grow,” says Verweij.

For some, the answer is to place greater restrictions on fungicides. “We need to selectively withdraw some azole-based fungicides from use on non-essential crops like the flower and bulb industry, and perhaps things like strawberries,” says David Denning, who researches fungal diseases at the University of Manchester, UK.

Against the resistance

As well as cutting back on the use of fungicides, everyone *New Scientist* spoke to for this piece agreed that we also need new antifungal drugs. These are harder to develop than antibiotics, in part because we are more closely related to fungi than bacteria. That means substances that kill fungi are more likely to be toxic to us. Clinical trials of potential antifungals can be especially difficult to run because those most vulnerable to fungal infections are often in more fragile health, and the relative lack of attention to fungal pathogens in general has translated into a lack of funding of work on new treatments.

Two drugs, ibrexafungerp and rezafungin, are being tested in trials of large numbers of people, while others are less far along. One of these, olorofim, is part of a new class of drugs that work by blocking production of pyrimidine, a key precursor of DNA. There are others at earlier stages of development, but it could be five years before new drugs are available for patients. When they are, many warn that we should learn from our mistake of using antifungals in agriculture. “When the new antifungal drugs come out, they should be used exclusively for the treatment of human disease, not as fungicides,” says Verweij.

There is another possible technique that could help us halt the rise in resistance: preventing fungal pathogens from disabling our immune defences. During gene expression, information stored as DNA is copied to produce messenger RNA, which is then copied to make proteins. In recent years, researchers have revealed how pathogens use so-called RNA interference to interrupt this process.

SELVANEGRA/GETTY IMAGES



Drug-resistant species of *Candida* yeast can cause deadly infections

Hailing Jin at the University of California, Riverside, has shown how *Botrytis cinerea*, a fungus that rots many food crops, can transfer small RNA molecules to its hosts to attack their defence mechanisms. She was able to genetically engineer tomato plants that are less susceptible to infection because they produce RNA molecules that undermine these assaults. She also found that fungal pathogens can take up short bits of RNA from the environment. “You could topically apply RNA molecules to the surface of plants so they can get into the cells of a fungus trying to infect them and silence their virulence or growth-related genes,” says Jin. Others are investigating whether azole-resistant *A. fumigatus* could be targeted in the same way.

It might seem like a strange time to highlight the risks of infectious disease agents other than the new coronavirus. Yet doctors report that people with covid-19 can be more vulnerable to dangerous fungal infections. A small study in India found that 2.5 per cent of people in intensive care for covid-19 developed treatment-resistant *Candida* bloodstream infections, and that *C. auris* was to blame for the majority.

Researchers have also identified dozens of cases of covid-19-associated pulmonary aspergillosis (CAPA), in Europe, Asia and South America. In some locations, as many as one in three people in intensive care with covid-19 also had CAPA. The combination of covid-19 and multi-triazole-resistant *A. fumigatus* has been found to be particularly deadly.

While the broader health burdens and death tolls of drug-resistant fungal pathogens aren’t making headlines, they are certainly large and growing. A critical lesson of the current pandemic is that we must boost our spending on infectious disease preparedness. “Covid-19 teaches us how a pandemic can emerge unexpectedly to have far-reaching impacts on our health, economy and social structure,” says Ghannoum. “We need to invest more in research and development, and prepare our defences – against all types of infectious pathogens.” ■



Nic Fleming is a science writer based in Bristol, UK. Follow him @NicFlem

"With AI, you might unlock some of the secrets about how life works"

Demis Hassabis is co-founder of DeepMind, a world-leading artificial intelligence company. His team has just cracked one of the hardest problems in biology. That's just the start, he tells Timothy Revell

WHAT IS AVAXHOME?

AVAXHOME-

the biggest Internet portal,
providing you various content:
brand new books, trending movies,
fresh magazines, hot games,
recent software, latest music releases.

Unlimited satisfaction one low price

Cheap constant access to piping hot media

Protect your downloadings from Big brother

Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages

Brand new content

One site



AVXLIVE • ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open <https://avxlive.icu>



IN THE run up to the match, Lee Sedol was feeling confident. He was about to play an artificial intelligence that had been trained to play the board game Go. But as one of the world's best players of the game himself, Lee thought he would easily win. "I thought AlphaGo was based on probability calculation and it was merely a machine," he said at the time. Even after he lost the first game of the match, Lee believed it was just because AlphaGo had made no mistakes. Then, in the now infamous move 37 of the second game, the AI seemed to be rewriting the rules of Go and played a move no human would have dreamed of. Lee, who ultimately lost the match 4-1, was dumbstruck: "This move was really creative and beautiful," he said.

This contest marked a pivotal moment in the development of AI, and Demis Hassabis was one of the main people responsible for it. In 2010, he co-founded the research company DeepMind and began

working on AIs that could play games better than people. At the time, Go was considered too hard for artificial intelligence to master. It has more possible moves than there are atoms in the universe. Yet the win over Lee in 2016 catapulted DeepMind – and Hassabis – to worldwide fame. AlphaGo's victory was the biggest moment in AI since IBM's Deep Blue defeated world chess champion Garry Kasparov in 1997.

Since then, Hassabis's firm, which is now a subsidiary of Alphabet, Google's parent company, has been honing its algorithms and looking beyond games. In November, its new AI, AlphaFold, cracked the devilishly hard problem of predicting protein structures. Proteins are strings of amino acids that fold themselves into incredibly intricate shapes and serve as the biochemical tools that make living things tick. Working out the shape of a protein usually requires years of experiments. AlphaFold does it without any. Hassabis believes this is just the beginning of what AI can do for science.

Timothy Revell: What are you trying to do at DeepMind?

Demis Hassabis: Our vision is to solve artificial intelligence. What we mean by that is to fundamentally understand intelligence and recreate it artificially, and then use that as a tool to help us understand the world and make a positive impact. Part of that is about advancing the pace of scientific discovery. The Hubble telescope allows us to see further into the cosmos, and that's how I see AI, as a generalised Hubble telescope that can help us make a lot more progress in many areas of science.

How do you know what sort of intelligence to try to encode in AI?

We take a lot of inspiration from neuroscience. I'm both a neuroscientist and a computer scientist; my first degree was in computer science, my PhD was in neuroscience. We've tried to bring both together, being inspired by the capabilities the human mind has and how it operates. ➤

The protein problem

What are the most exciting things you are working on?

There are so many projects going on. We try to identify problems in science that have a cross section of factors that we like. There has got to be a clear objective to optimise, and some training data. The other thing we look for is impact: is this a challenge that, if we solved it, would unlock whole new branches of scientific endeavour? Protein folding has all those characteristics. We're also looking at quantum chemistry, pure mathematics and areas of physics and materials science.

You had a big success recently with proteins (see "The protein problem", right). Why did you choose to work on them?

I think proteins are incredibly exquisite. They are like little bio-machines, transporting nutrients around your body. They are switches, they are motors, they are little factories. From a mathematical and computer science point of view, it's intriguing to see that biology at that level starts looking digital and almost computational code-like. There are only about 100,000 proteins we know the structure of. That's a tiny fraction of the 200 million or so proteins that are out there in nature.

If you could solve protein folding, then you could probably accelerate drug discovery. You might start unlocking some of the secrets about how life works much faster than you can with experiments, which are slow, painstaking and difficult. You could better understand disease. I think one of the big transformations in science over the next 10 to 20 years is more and more biology being understandable in this computational way.

What can AI help us find out about biology that traditional approaches can't?

A lot of science's low-hanging fruit that could be addressed by an Einstein-like lone genius was done in the early parts of last century. Now we are left with more complex systems that don't yield themselves to simple laws. Up until now, biology has been regarded as too chaotic and too complex to apply physics

Proteins are essential building blocks of life. Inside cells, they form everything from molecular machines for generating energy to tools for sensing the environment, digesting food and carrying out repairs. Each protein is made up of long strings of 20 or so different varieties of amino acid, which are easy to identify. The resulting proteins fold themselves up into complex 3D shapes, full of spirals and loops.

Determining the shape that the protein assumes based on its constituent amino acids is mind-bogglingly difficult. According to one estimate, there are 10^{300} possible configurations for a single protein. Working out the shape often requires years of laborious experiments and analysis. As a result, we only know the structure of a tiny fraction of the proteins that arise in nature.

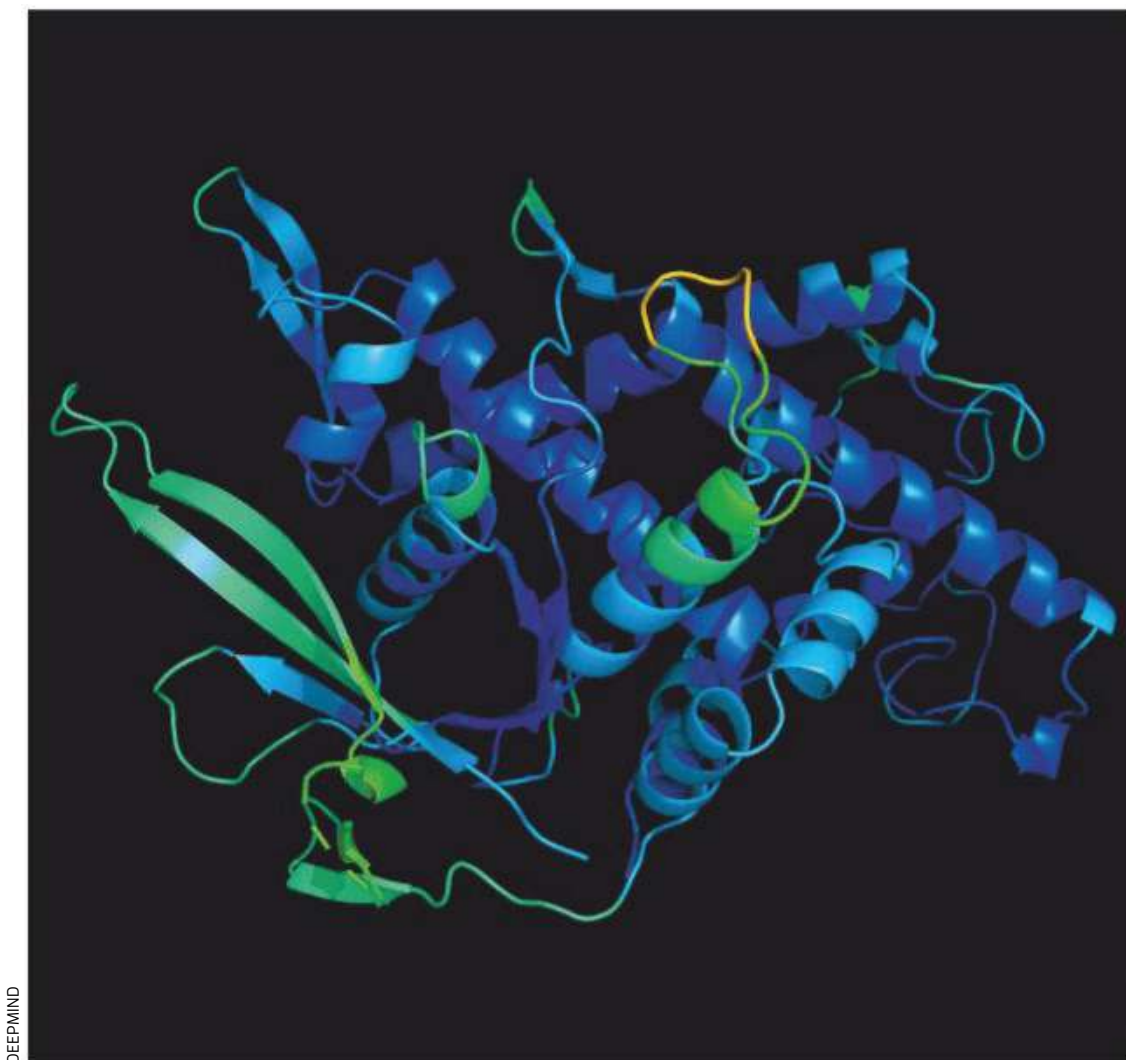
Since 1994, a competition called the Critical Assessment of protein Structure Prediction (CASP) has been held every two years to encourage progress. Teams that enter are given the sequence of amino acids that make up different proteins, whose 3D shape has been experimentally determined but not yet published. The teams compete to predict the protein shape from the amino acids. But little headway has been made until recently.

In 2018, DeepMind entered the competition for

the first time with an AI called AlphaFold. It won. But it did so with a score of just 60 out of 100 for accuracy in the hardest category. A score above 90 is considered as good as experiments performed by humans.

However, in 2020, a redesigned version of AlphaFold entered and won the competition again. This time, it fared much better with a median score of 87 in the hardest category. It scored above 90 for two-thirds of the proteins across all of the different categories. "I was really wowed when I saw it," said John Moult at the University of Maryland, one of the competition's organisers, at the time.

AlphaFold uses many of the same principles as DeepMind's other AIs, such as AlphaGo (see interview). Rather than being given instructions on how to predict a protein's shape, the AI learns using a technique called deep reinforcement learning. Through huge amounts of trial and error, using both simulations and real examples, it learns how to make predictions for itself. This means that AlphaFold doesn't use hardcoded human knowledge to make its predictions. That is probably just as well, because many iterations of the CASP competition have shown that we really aren't particularly good at making them.



The structures of proteins are fiendishly complex. It usually takes years of experimental work to deduce them

"AI is like a generalised Hubble telescope that helps us see further in many areas of science"

approaches to it, but perhaps computer science and AI can help bridge that gap. That's exactly where I think the AI sweet spot is.

You could think of it as having the world's best research assistant on tap for you. They can find patterns, pull together disparate bits from different papers and find connections between them. It would still require the human scientist to come up with the goal and why that is an important goal. A lot of work that PhD students do is not the most fascinating or creative. If you had automated systems that take out some of the drudgery, you could free up the students to think about creative solutions.

One criticism of systems like AlphaFold is that they can become very good at one task but they can't do anything else. Do we need a fundamental rethink of AI to make it more general?

No, but I think it's a reasonable criticism. We developed AlphaZero, which can play any two-player game with no modification, but it has to learn from scratch each time.

Its knowledge doesn't transfer. Some people would say: that's fine, you've got a general algorithm. Others find it unsatisfactory.

I would like that if an AI learns chess, it shouldn't be a complete zero at Go; something should transfer over. Humans do this extremely well because obviously we cannot afford to start from scratch at every task. That's called transfer learning and no one's cracked it yet with an AI. It's a super-active area of research and something I'm personally working on. Perhaps there are a couple more modules we need, like episodic memory and attention.

How would extra modules help?

It seems like the brain has at least two computational modes. You've got a cortex, which is quite slow at learning and needs quite a lot of examples, but it's very stable. On the other hand, you've got a hippocampus, which is what I studied for my PhD. It's a critical part of your brain and it is a superfast learner. That's how you remember what you had for lunch yesterday;

it's your hippocampus doing that.

You might ask why don't we just have one giant hippocampus. Fast seems better. Actually, the rat, which is pretty clever for its size, has a brain that is basically one ginormous hippocampus. But the problem is – this is my conjecture – if you have just a fast learner, and you learn something new, it's very volatile. By learning how to ride a bike, you might wipe out your piano-playing expertise. Because it's got to be fast, you don't have much control over what gets overwritten.

That doesn't sound ideal...

You don't want your whole brain to be that volatile if you're trying to build knowledge on top of knowledge. But on the other hand, you don't want to have to encounter the lion at the watering hole at dusk more than once before you learn that's really dangerous. So you need both systems and, presumably, some kind of transfer function between the two. That's partially what happens when we sleep. ➤

A brief history of DeepMind

The company made a name for itself training AI to play video games. Now it is helping diagnose disease and solve intractable scientific problems

2010

Demis Hassabis founds DeepMind along with Shane Legg and Mustafa Suleyman. The company was initially backed by a range of wealthy investors.

2014

DeepMind is bought by tech giant Google.

February 2015

DeepMind reports its first major success. It has trained an AI to play 49 different video games on the Atari 2600, a console released in the late 1970s. The AI learned how to play the games from scratch, just by watching pixels on the screen as it was played by humans. It went on to beat the highest scores of human players in 23 of the games.

March 2016

In an episode that made DeepMind world famous, its AI AlphaGo triumphed over Lee Sedol, then a world-leading player of the board game Go (see interview).

April 2016

DeepMind had signed an agreement with the Royal Free NHS Trust in the UK to develop an AI service for analysing patient data and automatically spotting signs of kidney problems. In 2016, *New Scientist* revealed that the agreement gave DeepMind access to a wealth of medical data from 1.6 million patients, including who visited them in hospital.

August 2018

A DeepMind system shows that it can spot the early signs of eye disease in retinal scans better than human doctors. The system had been trained on anonymised scans from 15,000 patients. It has the potential to flag up people who need treatment before their eye disease becomes irreversible.

December 2018

The company unveils AlphaZero, a version of AlphaGo that can learn to play other board games such as chess and a similar Japanese game called shogi. It was a stride towards a more general form of AI, which has long been considered an important goal.

October 2019

DeepMind's AI AlphaStar achieves grandmaster status in the video game *StarCraft*, ranking in the top 0.2 per cent of players. *StarCraft*, a real-time strategy game set in space, is difficult for AI because there is incomplete information about the virtual world – you can't see everything your opponent is doing – and there are a huge number of possible moves and tactics.

December 2020

DeepMind cracks protein folding. Its AI AlphaFold is so accurate at predicting a protein's shape from its amino acid structure that it is on par with experiments performed by humans (see "The protein problem", page 46).

Does that mean AI needs a form of sleep?

Potentially. We do work on that. If you look at our early work getting AI to play Atari video games, memory replay is one of the key reasons it works. Not only does our AI play the game, it replays key aspects of what it did back to itself. You could call it sleep, but, obviously, it's not actually sleeping. It's in an offline mode.

On the progress bar of AI, where you have a robot vacuum cleaner at one end and human intelligence at the other, where are we now?

I would say somewhere about halfway. But there are different schools of thought. Some people think we as a community with deep learning and reinforced learning are not on the right track, so there'll be some brick wall. Others on the pro side say, look, we have everything we need. It's now just a question of scaling up: more computers, more data and we'll eventually pop out a human-level general AI.

I think both camps are wrong. My view is that what we have invented so far is on the right track and is super-useful. But I don't think we have all the ingredients. There will be further leaps, maybe only a handful, that are required.

Has DeepMind done any research on covid-19?

It came in a bit too early for AI to be of much real help for this particular outbreak. God forbid, if there's another one in a few years' time, I would expect AI to play a bigger part.

The genetic sequences of the proteins in the virus were sequenced early on by Chinese researchers and some of the structures had been experimentally determined. But for a dozen or so of the proteins involved, we did not know the structures. At the time, we already thought our AlphaFold system was pretty accurate but it hadn't been battle-tested, so we didn't want to make big claims about the structures of those proteins. But we also thought we might be sitting on something that could be useful for the scientific community. So we immediately published our best models of those understudied proteins.



One of DeepMind's early successes was at the board game Go

enabled because of that. I would be very surprised if that doesn't happen in the next 10 years. We hope to be a big part of all that in a lot of different branches of science, from renewable energy – things like fusion – to quantum chemistry, material design and finding cures for diseases.

Nuclear fusion you say?

I probably shouldn't have mentioned that. But yes, I feel like there are some interesting areas of fusion that I think are amenable to AI, to do with the control of the plasma for instance. I have probably said too much, but in future we may have something to discuss about that.

That sounds rather tantalising. With so much going on at DeepMind, how do you spend your day?

I have a rather strange schedule, because my work and my life are all intermeshed. I have a two-day set-up. So during the day, I manage the company and do meetings. In the evenings, I start again. I'm a very nocturnal person, so I sit down again around 10 pm and go into the small hours of the morning. And that's when I write my research papers, read about and look into different areas, research them. That's my quiet time, and I love it. And I do that seven days a week.

It sounds like you don't have much time for sleep, which is important for humans as well as AIs.

Yes, I know, which is bad. I don't know how many more years I can work like this. And I know very well how bad it is for your brain, so I do try to get 6 hours at least, but I sometimes fail. On the weekends, I try to catch up by lying in, although that's not as good as getting a regular amount of sleep. I'm working on that, the sleep problem. ■

"What we have invented so far is on the right track. But I don't think we have all the ingredients"

Talking of existential threats, can AI help us with climate change?

One of our most famous pieces of work we did for Google was to control the cooling systems in the data centres that everybody uses when you watch YouTube and so on. We managed to save 30 per cent of the power that those data centres use by more efficiently switching on and off the fans and the pumps and all the other amazing equipment that is in these data centres. So that's obviously huge for cost-saving, but also for the environment.

You should be able to apply the same types of optimisation to other buildings or even a national grid. That would save a lot of energy. In the future, AI might contribute to things like material design or protein design, so that we have proteins that can break down waste plastics or create renewable biofuel.

Where will AI have the most impact in the next 10 years?

I hope to see dozens of breakthroughs on grand scientific challenges, and then many products, services and advances that are



Timothy Revell is *New Scientist's* comment and culture editor


scienceclocks.com
'Perfect gifts for science lovers'


FIBONACCI


CONICS


MOBIUS


DNA







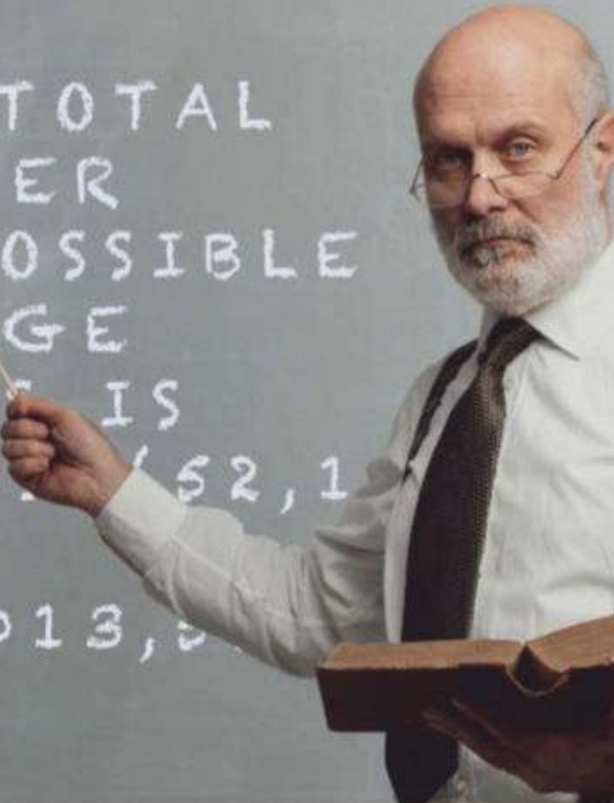

redmolotov.com
0161 706 0865

PROUD TO BE A
Girly Swot

We Do Mugs Too!

© Shutterstock

THE TOTAL
NUMBER
OF POSSIBLE
BRIDGE
HANDS IS
COMBINED 52,1
OR
635,013,5





www.bridgeclublive.com

Why not play one or more
of these on
BridgeClubLive?





www.bespokehandmadeshoes.com
Made To Measure Handmade Shoes
 Free Design Your Own Shoe Service



Review Our Customers' Feedback Online
100% Money Back Guarantee


 Any design shoe
£189.99


 Any design ankle boots
from £219.99


 Any design mid-calf
boot from
£399.99

We Make Large & Wide Sizes
150 Years of Shoe Making Tradition

WhatsApp : 07440022869

Phone : 02080904022

Puzzles

Try our quick crossword, quiz and brain-teaser **p52**

Almost the last word

Why don't birds freeze when flying at high altitudes? **p54**

Tom Gauld for New Scientist

A cartoonist's take on the world **p55**

Feedback

Elevator arrivals and dam dilemmas: the week in weird **p56**

Twisteddoodles for New Scientist

Picturing the lighter side of life **p56**

Science of gardening

The humble spud

Give your potatoes a head start on the growing season with the magic of chitting, says **Clare Wilson**



Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment @ClareWilsonMed

What you need

Seed potatoes

A cool and light place for storage

A garden centre

IN MY last column, I suggested growing blackcurrants, one of the easiest fruits to cultivate. Their vegetable counterpart in terms of difficulty level is the humble spud, and now is the right time to start planning your potato crop.

Unglamorous as they are, potatoes may not be everyone's first choice for home growing. But they taste noticeably better than shop-bought ones, especially when growing baby salad potatoes, and produce a harvest just a few months after planting. Because they can be so productive with regard to calories harvested, some historians say that the potato's arrival in northern Europe in the 16th century helped fuel the continent's population growth.

When I took on my allotment and didn't know where to start, old hands told me to put potatoes in the first strip of cleared earth because I could virtually forget about them until summer, when they would produce my first harvest. But you can also grow potatoes in the smallest of backyards, as they do very well in pots. Using containers also helps keep slugs away and takes less digging at harvest time.

Although potatoes aren't planted until March or April in the UK, once the risk of snow and frost has passed, it is time to buy your "seed potatoes", small, disease-free spuds from last year's harvest. You can get a head start on the growing season by storing seed potatoes in a cool and light place for a month or two, encouraging them to send out a few shoots. Called "chitting",



SHUTTERSTOCK/EMMA BREWSTER

this is typically done by placing the potatoes in egg cartons to hold them upright and exposed to the light. "They think it's time to get going," says Derek Stewart at the James Hutton Institute in Dundee, UK.

There is great debate about whether chitting is worth the bother, with studies giving mixed results on whether it boosts the crop. According to one UK trial, chitting does lead to a slightly bigger yield, but does so by making plants produce fewer yet bigger spuds. If your goal is lots of small potatoes, then chitting would be unhelpful. On the other hand, larger potatoes take less time to wash, and having to scrub off clods of earth is the one downside of growing your own. Big spuds are also easier to find

when you are digging them up.

If you choose not to chit, I would still buy your seed potatoes now because, by March, garden centres may be running low on stock and some varieties will be sold out. Just store the bag somewhere cold so they don't start sprouting shoots.

For years, I have been growing a variety called Charlotte, which is good for slug-resistance, but I am probably stuck in a potato rut. This year, I will be adding a row of Mayan Gold, said to be unsurpassed for flavour. I plan to experiment by chitting half of each kind and comparing the results – why don't you run a field trial of your own? ■

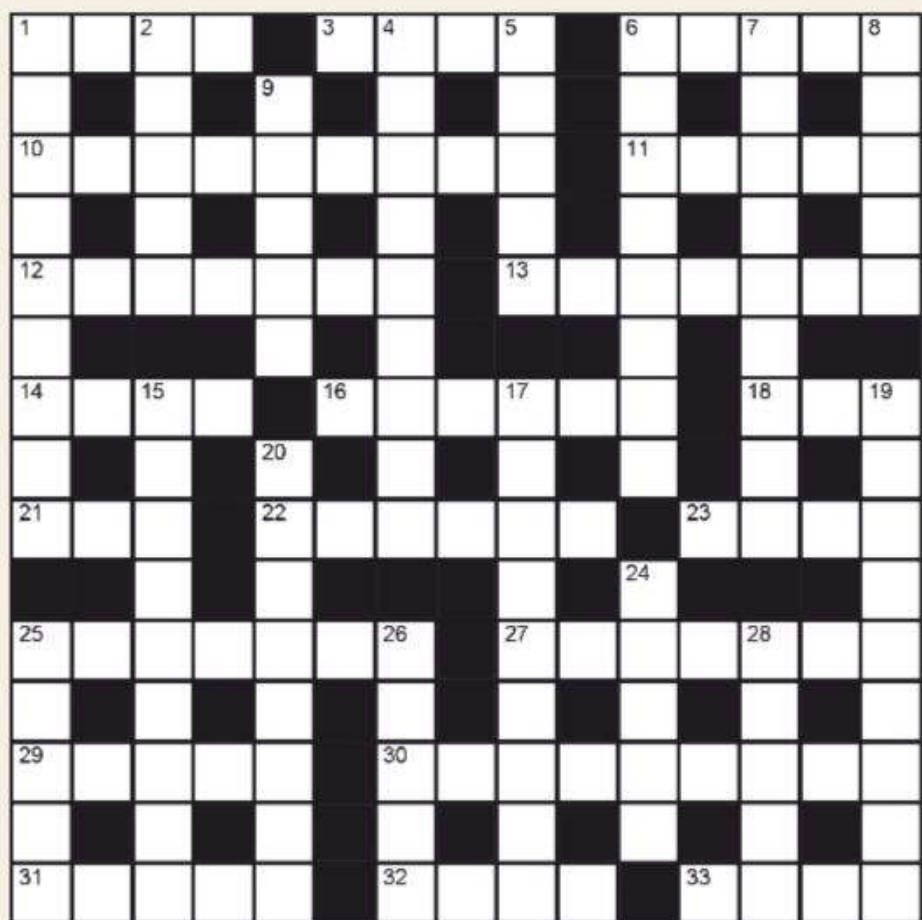
Science of gardening appears every four weeks

Next week

Citizen science

These articles are posted each week at [newscientist.com/maker](https://www.newscientist.com/maker)

Quick crossword #73 Set by Richard Smyth



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

- 1 Cylinder; London Underground (4)
- 3 Cease (4)
- 6 Collier, say (5)
- 10 Not rational (9)
- 11 Snake of the genus *Dendroaspis* (5)
- 12 Digestive enzyme (7)
- 13 See 19 Down
- 14 E, in the ICAO spelling alphabet (4)
- 16/25 Down Sports venue used for the Chicago Pile-1 nuclear reactor (6,5)
- 18 Ω (3)
- 21 2001: A Space Odyssey supercomputer (3)
- 22 CH_3CO (6)
- 23 Blood vessel (4)
- 25 More transparent (7)
- 27 Mosquito-borne disease (7)
- 29 Increased (5)
- 30 Surfactant used in cleaning (9)
- 31 Herb in the mint family (5)
- 32 Desert antelope (4)
- 33 Marvel mutant superheroes (1-3)

DOWN

- 1 Ordinal of 30 (9)
- 2 Marsupial also called a rabbit-eared bandicoot (5)
- 4 Skill; knack (9)
- 5 Tubular, coral-forming creature (5)
- 6 Extinct elephantids (8)
- 7 Unseen administrator in television series *The Prisoner* (6,3)
- 8 Respond (5)
- 9 Defecate (5)
- 15 50 per cent full (4,5)
- 17 Anatomical trait seen in, for example, the fiddler crab (9)
- 19/13 Across Code name for the Allied development of the atomic bomb (9,7)
- 20 Tennessee production base for the 19 Down/13 Across (3,5)
- 24 Plant life (5)
- 25 See 16 Across
- 26 Communication form based on electromagnetic waves (5)
- 28 Thin mucus (5)

Quick quiz #82

- 1 How many flavours of leptons are there?
- 2 What was the first commercially available arcade game?
- 3 On which island would you find subak, a sustainable irrigation system for terraced rice fields?
- 4 In what year was the giant-impact theory of the formation of the moon first proposed by Canadian geologist Reginald Aldworth Daly?
- 5 Where in the body of vertebrates is the maxilla?

Answers on page 55

Puzzle

set by Rob Eastaway

#94 Fastest fingers first

The contestants were lined up, each hoping to get into the Millionaire chair. First, they would need to get through the "fastest fingers first" round.

The host cleared his throat: "List these animals in order of the number of legs they have, starting with the most: A Fettlepod B Eldrobe C Sentonium D Quizzlehatch"

Guessing blindly, Jasmine went for CDBA, Virat chose CBDA and Finnarr picked ADCB, but none got all four right. In fact, they all got the same number of answers in the correct position.

Which has more legs, a Fettlepod or a Sentonium?

Answer next week



Our crosswords are now solvable online
newscientist.com/crosswords



GOVERNMENT OF INDIA

**Ministry of Education
Department of Higher Education
Technical Section - I**

Invitation of Applications for the post of Director, IIT Delhi

Applications are invited for appointment to the post of Director of Indian Institute of Technology (IIT) Delhi. The Director of an IIT is the academic and administrative head of the Institution. He/she is expected to have a minimum of 5 years' administrative experience and leadership qualities to head an Institute of National importance. The candidate/person should be a Ph.D. with first class or equivalent at the preceding degree, preferably in a branch of Engineering. In exceptional cases, candidates with Science, Mathematics or Management degrees may be considered. He/she should have an outstanding academic record throughout and a minimum of 10 years teaching experience as a Professor in a reputed Engineering or Technology Institute or University and should have guided Ph.D. students. The applicant should preferably be less than 60 years of age on the last date of receipt of the applications. The post carries a fixed pay of Rs. 2,25,000/- (Revised) per month, with allowances as per rules.

2. Interested individuals may apply giving their detailed resume in the prescribed format clearly bringing out research, teaching, industry-academia collaborations and administrative achievements, along with a two-page justification in support of their candidature, a two-page vision statement for the institution and contact details of at least two distinguished individuals well acquainted with their work. The application typed in the prescribed format along with enclosures may be sent by Registered/Speed Post to **The Under Secretary (TS.1), Department of Higher Education, Ministry of Education, Room No. 428 "C" Wing, Shastri Bhawan, New Delhi -110 001** so as to reach the Ministry on or before **20.01.2021**. The detailed advertisement and the format of application is available on the website (www.education.gov.in).

New
Scientist
Jobs

Bring your career to life

Looking to work in life sciences?
Search and apply for 1000's of jobs
from the number one destination
for science jobs.

newscientistjobs.com

Frozen flight

Birds fly at tens of thousands of metres high. Ice forms on the wings of planes at this altitude, so why don't the birds freeze?

Lucy Hawkes

University of Exeter, Devon, UK
Birds can sometimes reach astonishingly high altitudes. The record is a massive 11,278 metres by a Rüppell's vulture that collided with an aircraft. The resulting "snarge" – that is to say, the bird's remains – left on the plane provided robust evidence.

Birds almost certainly don't experience icing while flying at altitude for three reasons.

First, birds normally maintain their body temperature at about 40 to 41°C, higher than that of mammals. Flying is such hard work that it probably uses about twice as much oxygen per unit of time as running does, so birds are plenty warm as they fly about, even at very high altitudes.

Second, birds' feathers are a fascinating evolutionary

"The bird that holds the record for altitude, a Rüppell's vulture, collided with a plane. The remains provided the proof"

adaptation to not only flight, but also life outdoors. As well as being beautiful and providing lift and trim in flight, feathers keep birds warm and waterproof. They do this via complex microstructures that trap air and repel water. Birds also spend a lot of time preening their feathers to coat them in a layer of "preen oil".

The content of preen oil varies between bird species, but mainly contains monoester waxes and triglycerides, which are oily and repel water. Next time you spot a bird in the rain, marvel at how raindrops sit on top of its feathers as beads, rather than making the bird wet. That is preen oil at work. Indeed, one of the solutions used



ADRIEN BENSIEK/EYEM/GETTY IMAGES

This week's new questions

Shake it off Why do dogs like to shake themselves dry beside people, rather than doing this as soon as they get out of the water? *David Pitcher, Auckland, New Zealand*

Motion mystery Particles are in constant motion. What propels them? *Jon Watts, Esher, Surrey, UK*

to prevent accidents in aircraft flying through icing conditions is to use hydrophobic surfaces.

Lastly, most birds flap their wings at least some of the time when in flight, and this action would probably dislodge ice crystals if they were able to form.

Mike Follows

Sutton Coldfield, West Midlands, UK

Birds don't freeze because they generate heat during flight. In fact, they have to flap their wings even harder than usual to stay aloft at high altitudes because the thinner air provides less lift. Also, they aren't travelling as fast as a plane, so there is less wind chill. Besides, if they fly in formation, they shelter behind the leading bird.

Although the Rüppell's vulture holds the altitude record, I have a

new respect for the unsung mallard ducks that frequent lakes and ponds in the UK. They can migrate at altitudes of around 6.5 kilometres.

Niall Leslie

Yarker, Ontario, Canada

As a pilot in the two disciplines of gliding and powered flight, I can say that for appreciable ice to form, usually the surrounding temperature must be below freezing and there must be a quantity of liquid water (such as raindrops) or vapour (such as clouds) around.

You can avoid icing by simply flying where these things are absent, such as below the clouds, where it may be above freezing, or at high altitudes where the atmosphere is generally pretty dry. Birds do this quite easily, and

Why do wet dogs shake themselves dry when standing next to people?

I imagine that there may also be a degree of "anti-icing" built into the physical properties of their wings.

With aircraft, ice normally accretes along the leading edges of projecting items, such as wings, propeller blades and tail assemblies. For extended flight in icing conditions, aircraft typically rely on these areas being heated or having flexible bladders that are periodically moved pneumatically to break up the ice formations.

Colour confusion

I see the shoes (pictured) as mint green and grey, but a friend sees pink and white. Is this due to differences in our brains? Are we continually seeing different versions of the colours around us?



@DOLANSMALIK/TWITTER

Raymond Green

Kingussie, Highland, UK

My wife sees this shoe as pink and white while holding the magazine close up. However, by experimenting, we have found that from exactly 2.4 metres away, she sees it as green and grey. The change of colour is quite sudden. I see it as green and grey at whatever distance. We have never noticed any other differences in colour perception apart from "that dress" a couple of years ago.

■ *Editor's note: "That dress" is a photograph of a dress that went viral in 2015, which some people saw as blue and black and others as white and gold.*



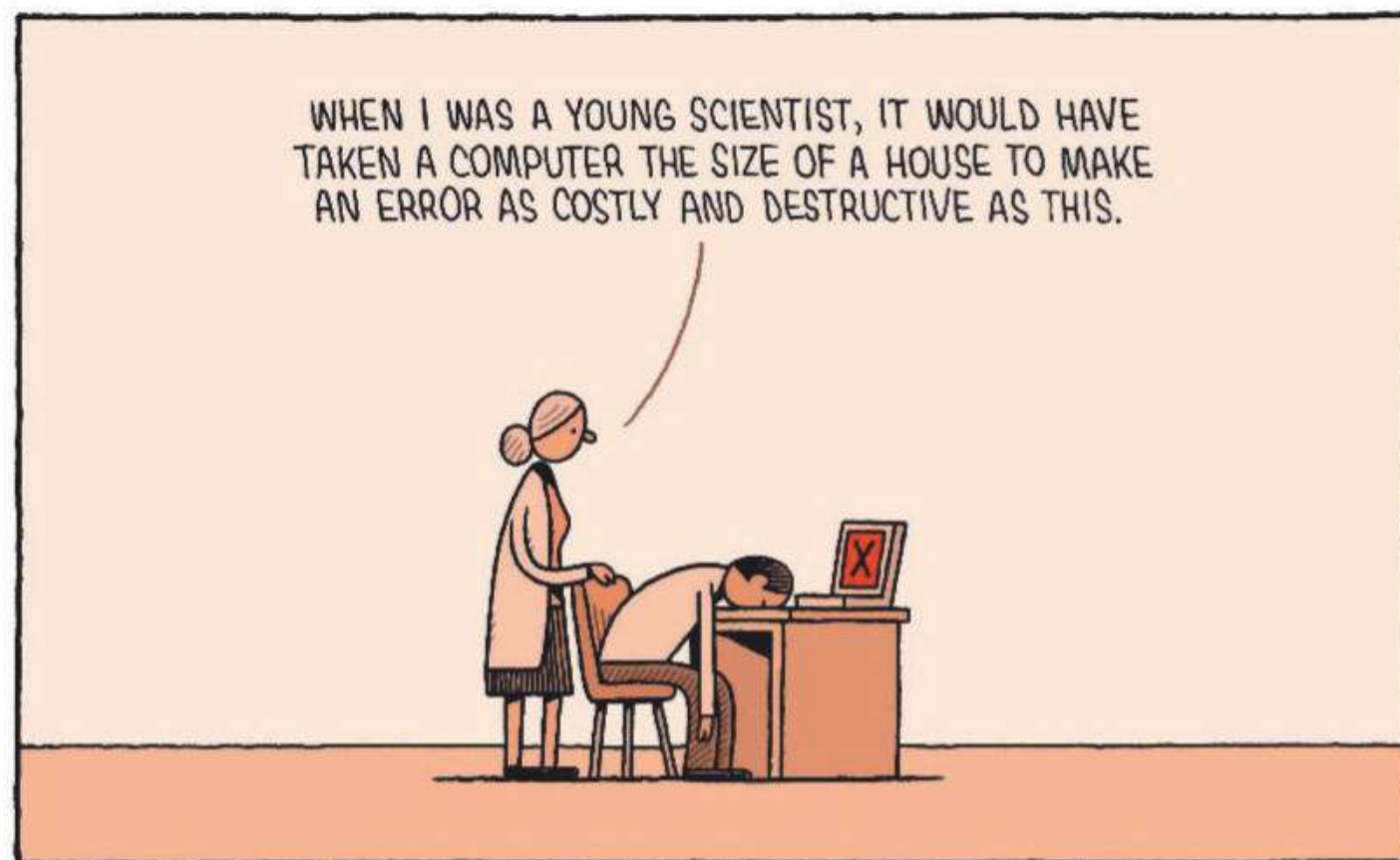
Want to send us a question or answer?

Email us at lastword@newscientist.com

Questions should be about everyday science phenomena

Full terms and conditions at newscientist.com/lw-terms

Tom Gauld
for *New Scientist*



Hazel Beneke

*Banksia Beach,
Queensland, Australia*

The letter writer's friend may have a form of colour blindness called deuteranopia, due to a lack of retinal receptors for green. My husband had this condition and often described grey clothes as pink, and vice versa. His brain learned to compensate, and this allowed him to see red berries and flowers on green bushes if viewed under artificial lighting.

Julian Money-Kyrle

Calne, Wiltshire, UK

Unless one of them is colour-blind, I would expect two people to agree on the shoes' colour if they saw them in the flesh. The issue is determining the actual colours from a photo. This process doesn't work well when we are looking at photographic prints, where the colours reflected by the ink depend on whether the lighting is continuous-spectrum (such as daylight and halogen light) or has spikes at specific wavelengths (such as fluorescent and LED light).

This can result in the phenomenon of metamerism, with colours matching under some lighting conditions and not others. For example, the enamel finish on a cooker I once bought matched the rest of the stove under daylight, but was noticeably greyer with the kitchen lights on.

However, there is a clue in this photo: the hand holding the shoe. The skin is roughly the same shade as the main body of the shoe itself, so unless the hand belongs to a corpse, I would say that the shoe is in fact pink and white.

“The brain has to make an educated guess about the true colour of any given item based on clues in the local environment”

James Stone

University of Sheffield, UK

The perceived colour of an object isn't a property of that object. It is an estimate made by the brain

that it attributes to the object.

The brain has to make an educated guess about the true colour of any given item based on clues in the local environment. For example, if an object is viewed under red light, then most of the light reflected from it is red, but the colour of the object is usually perceived correctly. I say usually because physically accurate perception depends on the brain knowing that the item is being viewed under red light, so that the effect of that red “wash” can be taken into account.

Consequently, when an object is viewed with little lighting context, as with this picture of a shoe, the brain has to fall back on its default assumption of the illumination.

The difference in observations of the shoe's colour suggests that the brain's default assumption for some people is that the illuminant is slightly red, and hence they see the shoe as white and pink. Others assume that the illuminant is slightly green, so perceive the shoe as green and grey-ish. ■

Answers

Quick quiz #82

Answer

1 Six: the electron, muon, tau, electron neutrino, muon neutrino and tau neutrino

2 Computer Space

3 Bali

4 1946

5 The jaw

#89 Sunday drivers

Solution

(12 December 2020)

Label the four cars 1 to 4 in decreasing order of speed. Think about car 4, driven by the Lentos. It can't set off first or last as this would lead to one big clump (either out or back). The Lentos also cannot set off third as this would give two clumps on the way back. And car 1 (the Prestos) cannot set off last, as it would have a clear run on the return, which we are told didn't happen.

This leaves four possible orderings on the outward journey: 1432, 1423, 2413 and 3412. Of these, only 1432 would involve two clumps going out and three coming back. So the cars left the hotel in the order: Presto, Lento, Andante, Vivace.

Uplifting message

As the world emerges blinking mole-like from the dark tunnel of 2020, let us hope to find sunlit uplands in 2021 – airy spaces less racked by existential fears where we are free to obsess once again about more trivial concerns. Such as “When will an elevator arrive?”.

This is the title of a new paper by physicists Zhijie Feng at Boston University and S. Redner at the Santa Fe Institute (arxiv.org/abs/2012.01471). Physics hasn’t yet been able to supply a precise numerical answer to that pressing (the button, repeatedly, in the belief it will make it come quicker) question, besides the felt 3 minutes plus/minus an eternity. But we do now have a very convincing, albeit, in the words of the researchers, “minimalist” mathematical model.

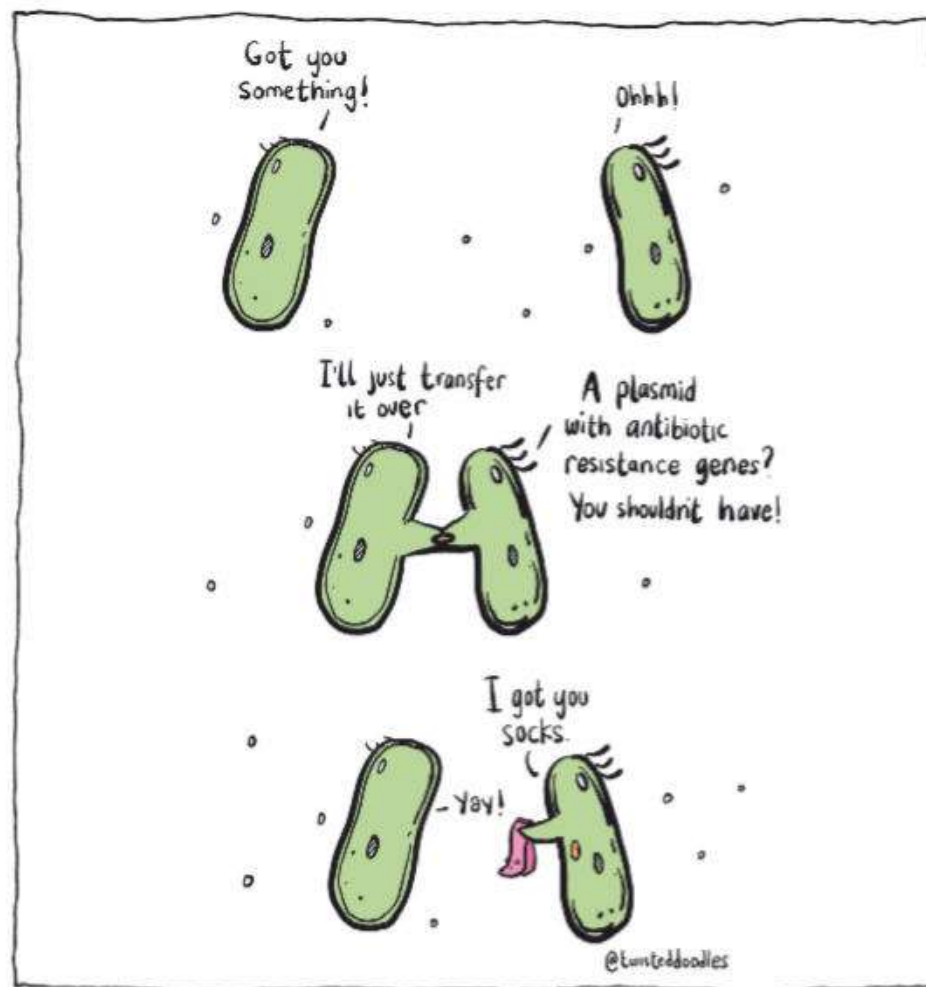
It starts, with admirable verve, with the case of the “Single Infinite-Capacity Elevator”, before ascending smoothly through “Single Finite-Capacity Elevator” and arriving, with a ding!, at “Multiple Finite-Capacity Elevators”, and a quantification of the degree to which, like buses, elevators bunch, synchronising to serve the same floors at the same time, which isn’t the one you’re on.

It is, the researchers humbly submit, “a small step in developing a physical understanding [of] elevator transport”. We’ll take that for the next time we are on our way to the penthouse stationery cupboard at *New Scientist* Towers and stand with a group of strangers with mien fixed on an LCD display of wrong numbers, suppressing the sudden desire to cough, or worse. Onwards and... upwards.

Après moi, le deluge

A new year is also a time to look back at how much worse things could have been, we just decided. We are cued by Pete Atkinson, who writes in from Toronto, Canada, with a bizarre nugget he found while investigating his stash of clippings. These are clearly as enduring as Feedback’s, as it

Twisteddoodles for New Scientist



Got a story for Feedback?

Send it to feedback@newscientist.com or

New Scientist, 25 Bedford Street, London WC2E 9ES

Consideration of items sent in the post will be delayed

concerns a report in the London *Times* from 23 July 1968.

“A Russian revival of an old scheme for damming the Bering Strait seems to have caused consternation among the Canadian planning authorities”, it begins insouciantly, opening a window onto a new vista of cold war madness. The plan to dam the 80-kilometre sea passage between Siberia and Alaska would apparently involve installing a battery of pumps to force cold water from the Arctic through the strait into the Pacific Ocean. This Arctic water would be replaced, in an extremely roundabout way, by warmer water flowing up from the North Atlantic Gulf Stream through the Greenland Sea and hey presto – a melting Arctic.

“Earlier versions of this suggestion, some of which have come from the United States,

involve the idea that nuclear power stations on both sides of the Bering Strait could be used to produce power and, at the same time, large quantities of warmish cooling water which would be discharged into the strait,” the report continues. “Because the current in those parts is predominantly south to north it had been suggested that a sufficiently large battery of power stations could melt a substantial amount of Arctic ice in a reasonable time.”

Feedback’s eyes bulge. *The Times* notes in passing the difficulty of predicting the precise consequences for the Arctic climate, but that concern is couched largely in terms of whether enough pumping power could be developed “to turn the Arctic into a comparatively clement place”. Far larger

stumbling blocks were the difficulty of reaching international agreement over the scheme, and the technical question of whether a sufficiently robust dam could be built across the strait. From the safety of a few floors up, we clasp our hands in silent prayer to the god of small mercies.

If you must...

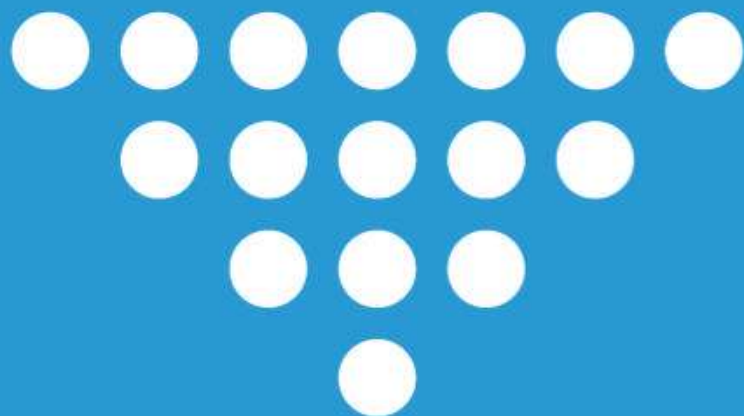
Continuing the environmental theme, Marc Abrahams sends us a “higher grade of nominative determinism” with news of a Dr Landsea, whose oeuvre includes “Effect of El Niño on U.S. landfalling hurricanes, revisited”, and a Dr Sealand, whose work largely concerns geological effects on groundwater storage. And with that, we consider nominations in this category closed for this year.

All must have prizes

Our clarification that at least two people have technically won both a Nobel and the alternative Ig Nobel prize (5 December 2020) has Toby Pereira, ominously, “thinking”.

He points out that if Bart Knolls, winner of an Ig Nobel for investigating foot odour and Limburger cheese as mosquito attractants, can claim a double with his Nobel peace prize as a staff member of the International Atomic Energy Agency in 2005, then any Ig Nobel prizewinner who was a citizen of the European Union in 2012 is also a dual laureate, as the EU won the peace prize that year. “This opens up the Nobel / Ig Nobel double to potentially a lot of people!” says Toby.

We sigh, and steel ourselves mentally for a flood of new claims, perhaps from those Ig Nobel laureates who want to stake a claim on the United Nations’ peace prize win in 2001. We also wonder what provision has been made in the UK’s EU withdrawal bill for the return of medals. That’s one that surely must have been elevated to the highest levels. ■



Join our community of world-class thinkers and professionals.

Come work in one of our five key research fields:



Cancer, Ageing and Somatic Mutation
Provides leadership in data aggregation and informatics innovation, develops high-throughput cellular models of cancer for genome-wide functional screens and drug testing, and explores somatic mutation's role in clonal evolution, ageing and development.



Cellular Genetics
Explores human gene function by studying the impact of genome variation on cell biology. Large-scale systematic screens are used to discover the impact of naturally-occurring and engineered genome mutations in human iPS cells, their differentiated derivatives, and other cell types.



Human Genetics
Applies genomics to population-scale studies to identify the causal variants and pathways involved in human disease and their effects on cell biology. It also models developmental disorders to explore which physical aspects might be reversible.



Parasites and Microbes
Investigates the common underpinning mechanisms of evolution, infection and resistance to therapy in bacteria and parasites. It also explores the genetics of host response to infection and the role of the microbiota in health and disease.



Tree of Life
Investigates the diversity of complex organisms found in the UK through sequencing and cellular technologies. It also compares and contrasts species' genome sequences to unlock evolutionary insights.

See our latest vacancies:
jobs.sanger.ac.uk

